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REPORT ON THE EMISSION AND CONTROL OF FUGITIVE COAL DUST FROM UNIT COAL TRAINS IN CANADA

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REPORT ON THE EMISSION AND CONTROL OF FUGITIVE COAL DUST FROM UNIT COAL TRAINS IN CANADA

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SUMMARY

The problem of fugitive coal-dust emissions from rail transportation has been recognized for many years. The increased rail traffic associated with increased coal production in western Canada was accompanied by public complaint over the environmental impact of fugitive dust emissions on communities situated along rail transportation corridors, particularly in British Columbia. By installing dust-control systems the coal producers made major strides in reducing the impact of fugitive dusting, but unfortunately, in spite of their efforts, severe dusting incidents have continued to occur and public concern has focussed on the need to develop improved dust-control measures. This report compiles the findings of studies and observations of the mitigation measures currently in use, reviews other control options and recommends methods for improving dust control.

Following the initial investigations in 1975, all of the major coal producers shipping coal by rail to Vancouver began spraying chemical sealants on the coal loaded in their railcars in order to control fugitive coal-dust emissions. Although dust emissions were significantly reduced following the advent of sprays, they were not eliminated and in 1979, Environment Canada, in conjunction with other federal government agencies, and the Province of British Columbia and with the cooperation of the coal industry, reopened the investigations into the fugitive coal-dust problem by establishing a monitoring station in the town of Agassiz, B.C. Five years of data from that field station indicate that continuing efforts by coal producers to reduce dust emissions have resulted in an improvement, expressed as a reduced ratio of visibly dusting trains to total train observations, but that the level of dust control provided by the existing dust control systems is not consistent. Trains with visible dust emissions assessed as "heavy" still occur; malfunctioning spray apparatus is cited by coal shippers as the most frequent reason for these "heavily" dusting trains.

Sprays are the dust control method preferred by the industry, and are likely to remain so for the near future, therefore Environment Canada commissioned a series of laboratory and field studies to investigate the reasons for the inconsistent performance of these systems. The most extensive study combined mine load-out observations with the assessment of crust-retentions on over 2000 rail cars; the results confirmed that spray systems were not producing the high level of performance efficiency and dust control predicted during the initial prototype tests. More importantly, however, the results of this and other studies indicated that the performance of the existing sealant spray systems could be substantially enhanced, and the frequency of system malfunction reduced, by upgrading the design of spray apparatus, by improving maintenance programs and by adopting improved operating procedures.

The coal mining companies are encouraged to adopt the recommendations listed in this report and to continue to work jointly with chemical suppliers and manufacturers to evaluate the optimum conditions for operating their spray equipment. Adopting these recommendations will result in improved spray system performance, improved dust-control consistency, and a consequent reduction in wind-blown coal-dust emissions.

Other control options and mitigation measures have been investigated. The most promising future technology appears to be the rigid, automated, railcar cover. Automated covers present the most positive and consistent form of dust control as well as other economic benefits. However, although estimates show that cover systems are potentially more costly to operate than spray systems, the major drawback to their implementation at this time is the lack of an off-the-shelf cover system capable of easy retrofit into the existing western Canada coal-transportation network. Further research is necessary to design, develop and test cover technology in order to obtain a better assessment of its economic and operational feasibility.

This report, and the recommendations herein, apply to all coal producers, railway companies and coal terminal operators involved in shipping coal over long distances by unit train in western Canada and the principal recommendation of this report is that each coal producer, and each coal terminal operator, should either improve existing dust-control equipment or install new, more effective coal dust-control systems in order to eliminate "heavily" dusting loaded and empty coal trains and to minimize the adverse air quality impact of fugitive coal dust on communities along the rail corridors. However, in view of the integrated nature of the coal transportation industry, the success of any new dust-control techniques or control system improvements will require the joint cooperation of the coal mining companies, the railway companies and the coal terminal operators.

RECOMMENDATIONS

The principal recommendation of this report is that each coal producer, and each coal terminal operator, in western Canada should either improve existing dust-control equipment or install new, more effective coal dust control systems in order to eliminate "heavily" dusting loaded and empty coal trains and to minimize the adverse air quality impact of wind-blown coal dust on communities along the rail corridors.

Automated car covers are the most effective dust control measure for rail transportation, however, there is no off-the-shelf system currently available for retrofitting to the complex western Canada coal-transportation network. Nevertheless, considering the long-term advantages to be derived from this future technology, the coal mining industry should continue the investigations begun by Environment Canada into automated cover technology. A prototype design, construction and testing program is required in order to develop a cover system which could be used in western Canada.

At present, chemical sealant applied at the mine load-out is the dust control measure preferred by the coal producers, therefore the recommended minimum requirement for fugitive dust control is a spray system, installed at each coal load-out, which is capable of covering the entire coal surface of each car with an adequate quantity of dust suppressant.

The measures listed herein define certain design, maintenance, and operating requirements for improving the performance of existing dust-control systems. Recommended monitoring requirements and performance goals are also included. These recommendations are based on the findings of laboratory tests, system performance monitoring studies and observations of the western Canada coal-transportation network by various investigators over the last decade.

However, it is recognized that the operation of mechanical dust-control systems, regardless of the design and maintenance procedures employed, cannot be perfect. Even though the number of "heavily" dusting loaded and empty trains will decline after producers and terminal operators implement improvements to their dust-control systems similar to those recommended herein, a few dusting trains may still occur. Therefore, in addition to the measures listed below, it is further recommended that the railway companies consider the implementation of a policy which requires all "heavily" dusting trains to reduce speed in communities where dusting will cause a nuisance pollution problem.

The recommendations for improved dust-control include:

a) The percentage of crust-cover-remaining (or crust-retention) on cars arriving at the unloading terminal (as measured by the observed ratio of crust-area-remaining to the total surface area of the load profile) is the present method of assessing spray system performance and dust control efficiency. A goal of 85% crust-retention was agreed to in 1975 by the coal mining companies, and a goal of 85% crust-retention is still considered the minimum performance requirement for spray dust-control systems. Coal shippers should ensure that the crusts on the cars in all of their loaded trains arriving at the unloading terminals in western Canada meet the 85% minimum crust-retention goal. However, crust-retention efficiency is not an absolute indicator of coal-dust emission control, therefore since the fugitive dust problem may persist in spite of achieving 85% crust-retention, the coal companies should work toward the goal of dust elimination rather than crust-retention in order to prevent coal dust impacts.

   Coal companies must continue to implement methods of improving the consistency and overall performance of their dust control systems in order to eliminate "heavily" dusting trains and to reduce overall dust emissions. They must strive to achieve a level of dust control that will reduce the quantity of emitted dust to a level that is acceptable to communities and citizens affected by nuisance coal dust pollution from coal trains.

b) Following the approach adopted by other industries with respect to corporate responsibilities towards environmental control, the coal producers shipping coal to terminals in western Canada should implement year-round monitoring programs to assess the effectiveness of their dust control measures. These self-assessment programs should include both assessments of crust-retention and en route dust-monitoring programs.

   At each unloading terminal checks should be made of a statistically significant number of coal cars and unit trains in order to demonstrate that the 85% minimum, or higher level, crust-retention goal is being achieved.

   Coal producers should cooperatively implement and operate air quality monitoring stations at selected sites along the rail transportation corridors where fugitive coal-dust pollution is a concern. Visual observation of dusting trains should be employed. In view of the historic and continuing concerns over nuisance coal dust impacts from communities in the Fraser Valley of British Columbia the air quality monitoring along this route should be implemented as soon as possible.

c) To achieve and maintain a high level of dust-control efficiency the following minimum requirements for the design and operation of chemical spray facilities are necessary:

- Each mine should implement, and adhere to, a thorough maintenance schedule for their spray systems which include pumps, mixing equipment, spray nozzles, spray headers and load-levelling devices. All spray headers and nozzles should be purged and tested, plus the spray patterns and the solution consistency verified before each train is loaded and strayed. Load-levelling devices should be checked for correct operation before each train is loaded.

- Training programs should be developed and load-out operators trained in the proper operating procedures for chemical spray systems and load-levelling devices. The importance of correct equipment operation for successful crust-retention performance and high dust-control efficiency should be emphasized in these training programs.

- Each coal mining company equipped with a spray system should install an effective load-levelling device capable of obtaining the flattest possible profiles on their loaded coal cars. Side ridges, humped profiles, and steep end-slopes should be significantly reduced or eliminated. Load-levelling devices should be designed to adjust (or be adjusted) to the height of all sizes of coal cars being loaded.

- Chemical spray systems should include the following design features:

  - spray patterns should be protected from distortion by wind;
  - freeze protection measures (or equipment) are required for all exposed piping, headers and nozzles to prevent the freezing of fluids during the worst of winter conditions;
  - nozzle patterns must be designed to coat all of the exposed coal surface on every car;
  - sprays must turn on and off rapidly in order to effectively coat all critical coal surfaces near the front and rear of each car;
  - the spray system should incorporate mixing and flow-metering equipment which will ensure the uniform application of evenly mixed sealant chemicals, of the desired concentration, over all coal surfaces irrespective of train speed through the load-out.

- Each mine-site spray installation should be equipped with two separate spray units, a primary and a secondary. Each of the spray units should employ separate pumping equipment, piping, spray headers and nozzles. The spray headers and nozzles of the secondary spray unit should be physically separated from the first spray unit and at sufficient distance to allow an operator to identify problem cars and activate the second spray unit. An operator should inspect each car as it is sprayed; all cars identified by the operator as unacceptable should be sprayed by the secondary spray unit.

Both spray units should conform to the design criteria listed herein and the secondary spray unit should have access to sufficient chemical sealant to spray an entire unit train. In the event of the total failure of the primary spray unit the secondary unit will therefore serve as a complete standby or back-up spray system.

- Chemical suppliers should establish the optimum operating procedures for their products and the coal producers should endeavour to employ these optimum procedures when spraying their unit coal trains. In addition, the mining companies and chemical suppliers should continue the testing of new and improved sealant chemicals and other methods of improving sealant crust-retention performance.

d) With respect to the dusting problems associated with loose or undumped coal, companies should adopt the following measures:

- Each coal mining company should incorporate a sill-sweeping device into its load-levelling system to remove coal from the top sills of all coal cars.

- Each coal terminal operator should install and operate a car wash to clear sills and exterior car surfaces of loose coal prior to the cars commencing the return journey to the coal mines. However, since an exterior car wash will not remove coal from the inside of dumped "empty" cars, the feasibility of interior car cleaning equipment, designed to eliminate return-car dusting and coal carry-back, should be investigated by the coal mining companies and the terminal operators.

- The coal mining companies and the terminal operators should continue their investigations of side-release agents, thaw sheds and other methods for improving car dumping and eliminating coal carry-back.

e) The railway and coal mining companies should cease the practice of removing coal from overloaded cars by "gouging" the surface or they should implement procedures to level and respray all cars whose loads have been corrected.

f) To improve loading procedures the railway companies should endeavor to group cars of the same height, either as complete train sets or as groups of similar cars within the same unit train. This practice will simplify the loading operator's task and should contribute to attaining flat coal profiles on a more consistent basis.

GLOSSARY OF TERMS

In the text of this report the following definitions apply:

1	Automatic Car-Indexing	-	The cars in the unloading loop at a terminal are automatically advanced through the rotary dumper by a hydraulic ram, not the diesel engine units.
2	Chemical Binders or Chemical Sealants	-	See Sealants.
3	Chemical Sealant Spray Dust Control System	-	The apparatus installed at a coal mine load-out which is designed to apply (spray) chemical sealants for coal dust control. These systems include: chemical mixing and storage tanks, pumps, values, flow meters, controls, sheds, piping, headers, nozzles and load-levelling equipment.
4	Clean Coal	-	The washed, product coal as shipped to market.
5	Coal Carry-Back	-	Coal retained in dumped or emptied cars. During cold weather coal often freezes and remains inside cars during the return trip to the mines. Loose coal can also remain in dumped cars during warm weather.
6	Crust or Crust Cover	-	A crust formed over a coal load as a result of applying chemical sealants to the surface.
7	Crust-Retention, Crust-Remaining, or Crust-Cover-Remaining	-	The top surface crust area remaining divided by the total coal surface-area of a loaded car, expressed as a percentage, as observed at the end terminal.
8	Dumper	-	See Rotary Dumper.
9	Dustfall Bucket	-	A device used to collect settleable particulate matter.
10	Fine Dust	-	Coal particles small enough to become wind-entrained and to carry from the surface of loaded coal cars.
11	Fines	-	A coal industry designation for the smaller coal sizes separated at a coal wash plant.
12	Frozen Coal Carry-Back	-	See Coal Carry-Back.
13	Fugitive Coal Dust	-	Coal particles emitted from loaded coal trains as a result of wind entrainment.

14	Gouging	-	The practice of removing coal from overloaded (by weight) cars in order to meet railroad capacity restrictions. A front-end loader or similar device is typically used.
15	High-Volume Sampler	-	A filtering device used to measure total suspended particulate matter.
16	Load-Leveller	-	A device usually dragged across the irregular coal surface of a loaded car. It is designed to flatten the coal profile.
17	Load-Out	-	The coal car loading facility.
18	Load Profile	-	The shape of the top surface of the coal load in a rail car, viewed from either the side or the end.
19	Nuisance Pollutant	-	A substance emitted to the environment that substantially alters or impairs the quality of the environment but is not classified as a health hazard to humans.
20	ROM Coal	-	Run-of-Mine or raw coal as mined, before it has undergone any form of treatment (washing) or beneficiation.
21	Rotary Dumper	-	An unloading device that inverts coal cars to dump the load.
22	Sealants	-	Chemicals applied as solutions or emulsions to the surface of loaded coal to seal in dust particles. Also referred to as Chemical Binders, Chemical Sealants and Sealant Chemicals.
23	Sealant Chemicals	-	See Sealants.
24	Sealant Crust	-	A surface coating provided by applied chemical sealants.
25	Sealant Volume	-	The quantity of concentrated, commercial-strength chemical sealant applied to each car.
26	Sill	-	The top flat surface of the side and end walls of a coal car.
27	Solution Volume	-	The total quantity of solution (or emulsion), obtained by mixing the commercial sealant (sealant volume) with water, applied to each car.

28	Spray Systems	-	The equipment installed to apply chemical sealants to coal cars.
29	Trestle Dumping	-	An unloading system used with bottom dumping coal cars. Cars run onto an elevated trestle and unload through the bottom of the car.
30	Tonne	-	A metric ton.
31	Unit Train	-	A train carrying only one cargo from loading point to unloading point.
32	Wind-Blown Coal Dust	-	The same as fugitive coal dust.

REPORT ON THE EMISSION AND CONTROL OF FUGITIVE COAL DUST FROM UNIT COAL TRAINS IN CANADA

1 INTRODUCTION

Coal dust blown from rail cars can be a source of nuisance air poilution in residential communities situated along transportation corridors. Public complaints about nuisance coal dust from coal trains arose in the early 1970's in British Columbia where significant coal train traffic existed as a result of moving coal for export from mines in western Canada to tidewater terminals.

In addition to the nuisance problems, coal dust blown from trains represents a loss of energy and is a recognized economic loss for Canadian coal producers. The problem of lost revenue resulting from coal losses during rail transportation has been under investigation in the U.S.A. since the 1960's (Ref. 1).

In the mid-1970's, in order to ameliorate the problems of product loss and nuisance dusting, the major western Canada coal mining companies installed spray systems to treat the coal surfaces of their loaded cars with dust suppressant chemicals before shipment. The application of sealant chemicals has significantly reduced dust emissions en route, however, complete dust abatement has not been achieved and dust emissions from unit trains continue to be a problem, principally in communities along the transportation corridors in southern British Columbia.

Since 1979, federal and provincial government agencies in conjunction with the coal industry have been involved in renewed investigations with respect to various aspects of wind-blown coal dust emission and control. This report provides a comprehensive review of the fugitive coal dusting problem as associated with unit coal trains and includes: a history of the problem in western Canada, an assessment of coal dust from unit trains as a nuisance air contaminant, a review of the work performed by or for various groups in response to the problem, a discussion of problems with the existing dust control systems, a review of other control options, and a list of recommendations for improving fugitive coal-dust control.

Please note, this report addresses only the problem of fugitive coal-dust emissions, the environmental impact of diesel engine exhaust emissions is beyond the scope of this work.

2 BACKGROUND–FUGITIVE DUSTING FROM UNIT COAL TRAINS

2.1 Origins of Concern

By 1973 nuisance pollution and the nuisance soiling caused by fine coal dust blown from unit trains was causing considerable public concern in many of the small communities along the main rail lines in southern British Columbia. Concern about the air-borne transport and deposition of coal dust in the communities of Cranbrook, Kamloops, Agassiz and Surrey was expressed by the public as numerous complaints to railway companies, operating mines, municipalities, Members of Parliament and government agencies. Supportive evidence in newspaper articles also highlighted the pollution aspects. (Ref. 2). Most of the complaints relating to nuisance coal dust pollution came from citizens and town councils in communities located from Kamloops to Vancouver. Details with respect to the areas where complaints were most frequent are presented in References 2 and 3.

2.2 Response - Initial Tests and Mitigating Measures

In 1973, in response to this public concern, Environment Canada initiated an Ad Hoc Committee on Coal Dust Nuisance from Coal Transport comprised of federal/provincial government and industry representatives. This committee determined that remedial action was required and initiated a series of tests to evaluate the effectiveness of sprayed chemical sealants as a method of dust control. After completing these studies in 1975, all major western Canada coal producers exporting coal through Vancouver agreed to spray the coal surface of every loaded rail car used to transport product from their respective mine sites to the British Columbia terminals (Ref. 3).

The coal mining companies operating this new and relatively unproven equipment were optimistic about its ability to produce dust abating surface coatings over their coal cars. The mining companies agreed that a minimum of 85% of the surface of the coal load in each car (arriving at an end terminal) would be covered with sealant crust and furthermore, that a 90% coverage should be achieved by October, 1975. Some investigators were even more optimistic of control system performance improvements and anticipated that coverages approaching 100% would be provided by the end of the 1970's. (Ref. 2).

2.3 Renewed Investigations

The emission of coal dust from unit trains and the related complaints about nuisance soiling subsided after sealant sprays became operational. However, they did not

disappear and by 1979 the increasing number of nuisance dust complaints and reported dusting incidents prompted Environment Canada to reopen the investigations with respect to the dusting problem. The first step in an Environment Canada program to address the renewed complaints about dusting trains was to install, in 1979, an air quality monitoring station in the town of Agassiz, B.C. at a location where the rail lines pass through a residential area of the town (Area 5 in Figure 1).

In addition to dust monitoring, an observation program was implemented to record visible dust episodes for both loaded and empty coal trains. A total of 3220 loaded and empty coal trains were assessed for dust emissions between January, 1979 and January, 1984. A summary of the visible dusting incidents recorded at the monitoring station is presented in Table 1 (Ref. 4).

The visible dusting observations from the Agassiz monitoring station have provided a method of assessing dusting trends and of reporting on the performance of the coal companies' dust control systems. Since 1981, any train assessed at the Agassiz monitoring station as "heavily" dusting has been reported to the coal mining company concerned so it may investigate the train's history for possible loading or spray system malfunctions. The mining companies have readily agreed to this program in order to improve the performance of their spray systems.

The Province of British Columbia and the coal mining industry have also conducted dust monitoring studies at selected sites along rail corridors in order to assess the extent of the dust pollution problem and to test the performance of dust control systems (Refs. 5 and 6).

In addition to the monitoring program at Agassiz, Environment Canada, in collaboration with the Province of British Columbia and with the cooperation of the coal industry, commissioned a series of studies to assess the continuing problems with respect to fugitive coal dust, to evaluate methods for improving the performance of the existing dust control systems, and to investigate the potential of alternative dust abatement techniques.

In 1982, three studies commissioned by Environment Canada relating to the fugitive coal dust problem were completed: the testing of coal dust for genotoxic activity (Ref. 7), a laboratory performance evaluation of latex sprays (Ref. 8), and a feasibility study of automated car covers (Ref. 9). Two other investigations were completed in 1983, an extensive spray system performance evaluation (Ref. 10) and a laboratory evaluation of unit train dust emission factors (Ref. 11). A program designed to evaluate ambient particulate monitoring equipment as coal dust collection devices plus an assessment of

FIGURE 1 MAJOR COAL - RAIL TRANSPORTATION ROUTES IN CANADA

TABLE 1 OBSERVATIONS OF VISIBLE DUST EMISSIONS FROM UNIT TRAINS - AGASSIZ, BRITISH COLUMBIA*

	LOADED COAL TRAINS				EMPTY COAL TRAINS			
		VISIBLE DUSTING ASSESSMENT				VISIBLE DUSTING ASSESSMENT		
YEAR	TOTAL OBSERVED	HEAVY	MEDIUM	LIGHT	TOTAL OBSERVED	HEAVY	MEDIUM	LIGHT
1979	309	23	21	29	233	3	5	7
1980	323	15	12	31	278	1	4	11
1981	459	20	12	29	290	1	3	4
1982	370	15	9	25	252	2	2	4
1983	363	11	12	16	286	0	1	2
January 1984 Only	31	7	4	1	26	2	3	2
Total	1855	91	70	131	1365	9	18	30

* Ref 4.

coal quantification analysis techniques was completed in the spring of 1984 (Ref. 12). The results of these studies are discussed in Section 3.

The major coal mining companies in British Columbia are active in two industry oriented committees which were formed to investigate the problems of fugitive coal dusting from unit trains: The Northeast Coal Technical Committee on Coal Dust and The Elk Valley Coal Producers Coal Dust Committee. Through these committees, and independently, the coal producers have initiated or been directly involved in studies designed to evaluate and to improve the performance of their dust control systems. The results of several of these studies have been published and are available to the public (Refs. 3, 6, 13, 14, 15, and 16).

3 PROBLEM ASSESSMENT

3.1 Unit Coal Train Operation

In order to assess the problem of wind-blown coal dust from rail transportation it is necessary to understand and appreciate the concept of the unit train and the implementation of that concept as used for the transport of coal in western Canada. Many of the difficulties encountered in the design and operation of systems for the control of fugitive coal dust emissions result from certain features inherent in the design and operation of unit coal trains.

Unit trains, for reasons of economy and efficiency, haul only one type of cargo from a loading point to an unloading point or destination. Although stops do occur (prime movers are added to or removed from these trains in the mountains), no cargo is delivered or picked up en route and the shunting of cars is kept to a minimum.

A modern unit train operation is predicated upon efficiency, therefore the design of the principal components, the loading facility, the rolling stock and the unloading facility, has been integrated in order to achieve the maximum economy and speed of operation. The three components of the typical unit train system, the load-out facility, the coal cars, and the rotary dumper, are illustrated in Figures 2, 3 and 4 respectively. (Refs. 9 and 17).

A typical unit coal train in western Canada consists of approximately 100 open-top gondola cars. The combination of 100 coal cars plus caboose is referred to as a train set. Coal cars in unit train service in Canada are owned by a number of different agencies: the coal mining companies, for example Devco in Nova Scotia; the end users, for example Ontario Hydro on the British Columbia and Alberta to Thunder Bay routes; the private leasing companies, for example Procor; and the two major railway companies. The leasing companies lease coal cars to both the coal mining companies and the railway companies. The coal car fleets and train sets of the railways in western Canada in 1981 were approximately as listed in Table 2.

Railway rolling stock is manufactured in batches and although there are only two or three basic designs for gondola cars, manufacturing tolerances and minor design changes between batches have resulted in coal car fleets where individual cars within a train set can differ with respect to load capacity, tare weight and dimensions (Table 3). In general, for coal service, the Canadian railways employ 91 tonnes (100 short ton) gondola cars. Detailed descriptions and illustrations of the gondola (or bathtub) coal cars are presented in References 2, 3, and 9.

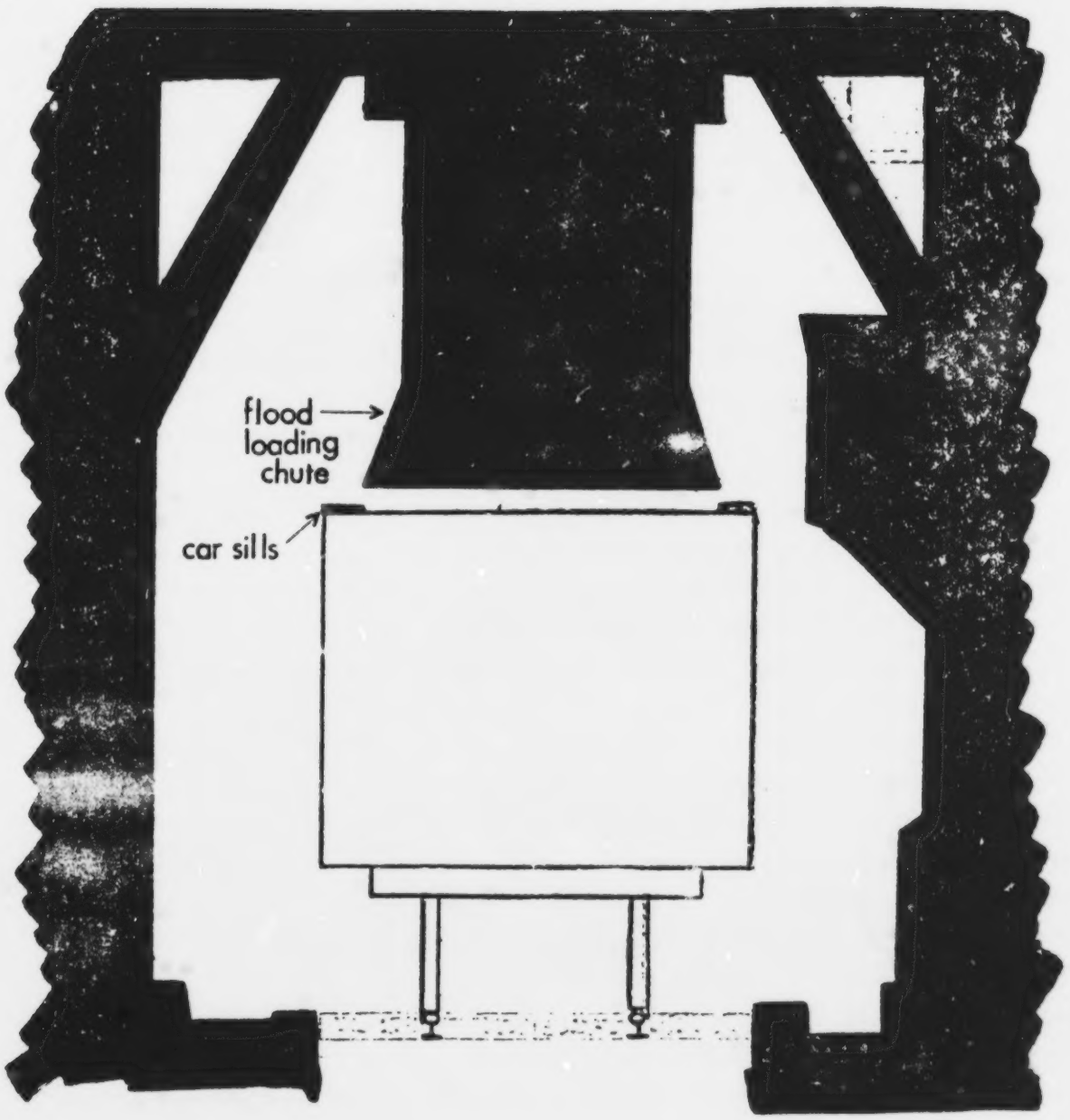


FIGURE 2 COAL CAR LOAD-OUT FACILITY

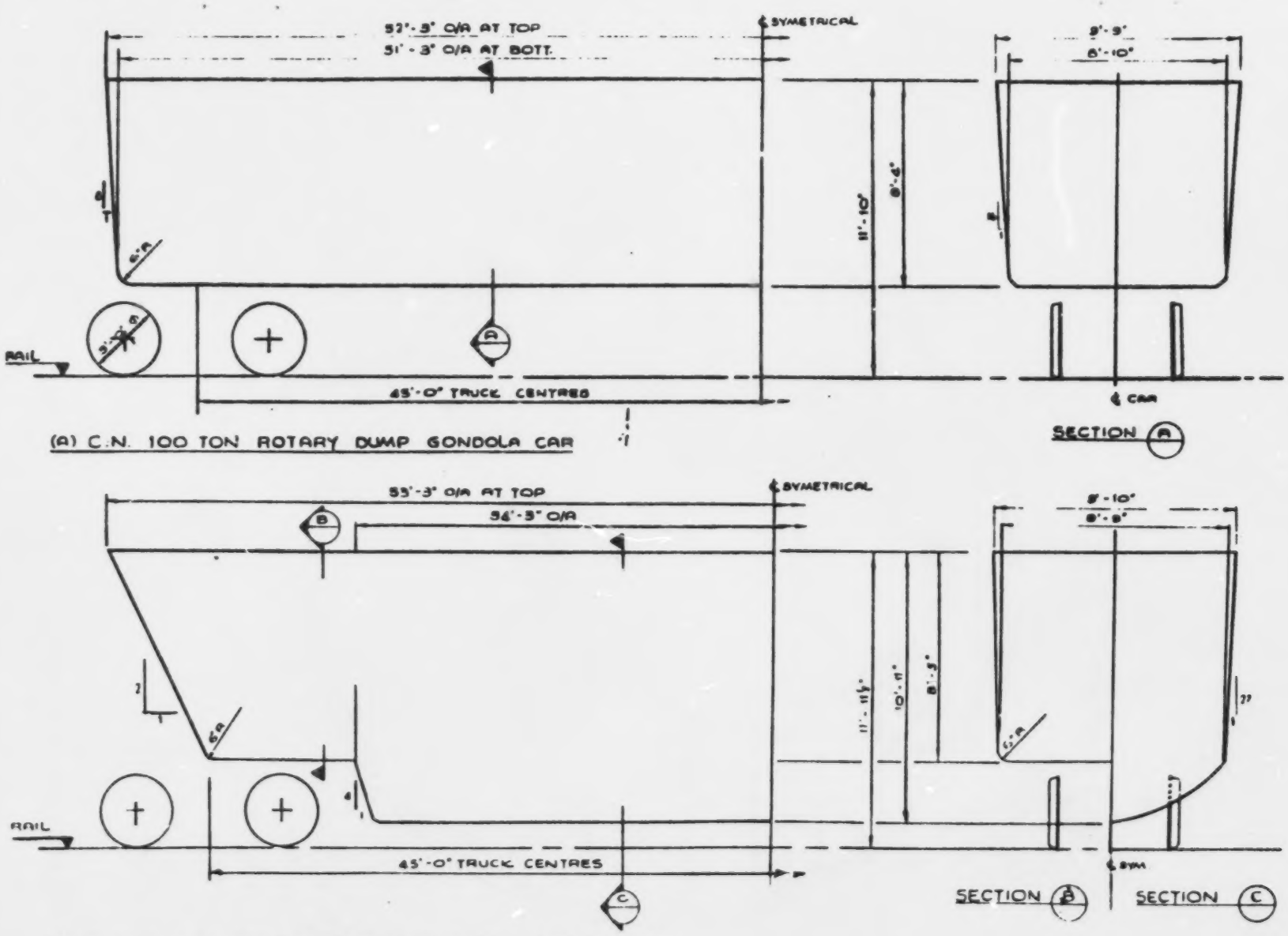
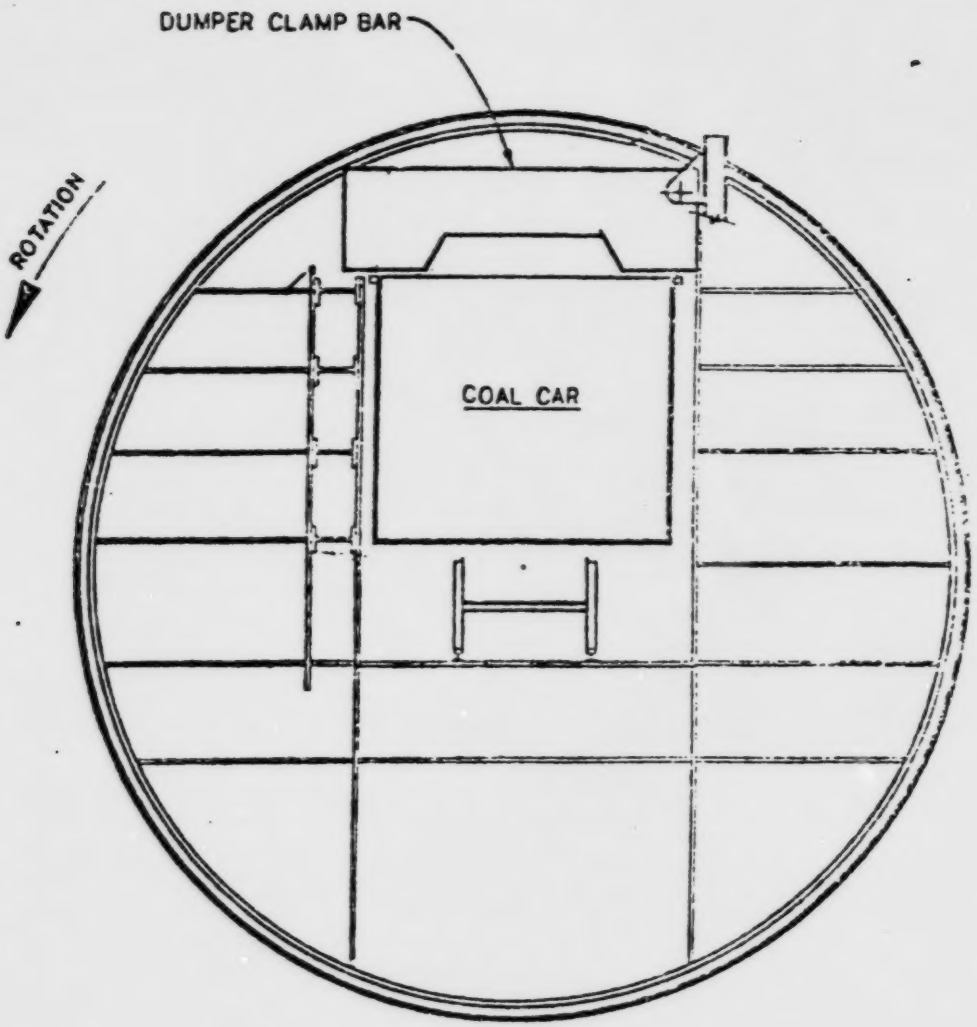


FIGURE 3 RAIL CARS USED FOR UNIT COAL TRAIN SERVICE



END VIEW OF DUMPER

FIGURE 4 ROTARY COAL CAR DUMPER

TABLE 2 COAL CAR FLEETS IN WESTERN CANADA (1981)

Railway Company	CPR	CNR	CNR* Increase	BCR
Train sets	15	14	10	*
Total Cars	1600	1370	980	100

* In 1981, BC Rail employed its leased coal cars in mixed freight trains. The "CNR Increase", shown in this table, began, in 1983, to service the new BCR/CNR northeast B.C. to Prince Rupert coal network.

Note: As published in Reference 9.

In spite of size variations certain train sets comprise cars of similar size and construction so that the sill height, an important dimension with respect to coal loading, is approximately the same for all cars in the train. Unit trains operated by the CNR which service northwest Alberta, the new BCR/CNR train sets servicing the northeast B.C. Coal Development, as well as the Ontario Hydro trains loaded in southern British Columbia are in this category. However, most of the unit coal trains operated by the CPR which service the coal mines in southeast British Columbia and which travel the Fraser Valley route to Vancouver comprise cars of different design and manufacture within the same train set. Consequently the sill heights of the cars within these CPR train sets will often vary from car to car (Refs. 8, 9, and 18). The CPR is also experimenting with an aluminum car which has a considerably higher sill than most of the steel cars, Table 3. There are only a few of these cars in service, and they appear randomly throughout the southeast B.C. train sets.

The largest coal exporting mines in western Canada, at peak capacity, may load two unit trains per day, seven days a week. Speed of operation is therefore essential in order to keep handling costs, rail charges and unit train turn-around times to a minimum. The mining companies attempt to fill the 100 cars in a train set in four hours or less, therefore at the mine load-outs, in order to load approximately 10,000 tonnes of coal within this four hour time limit, unit trains remain in motion during the loading operation. The typical speed through a load-out facility is 0.5 km/h (0.3 mph).

In order to load moving cars, the mining companies have developed a variety of techniques and load-out designs. The designs vary significantly from mine to mine.

A unit train of approximately 100 cars plus the associated engine units and caboose is approximately 1.6 km (1 mile) long and the standard procedure is for the train

TABLE 3 COAL CAR DIMENSIONS

	CPR Bathtub	CPR Aluminum "Bathtub"	CNR Gondola Car
Length coupler to coupler	58'-7"	58'-7"	58'-7"
Truck spacing (bogie centres)	45'-0"	45'-0"	45'-0"
Axle spacing	5'-10"	5'-10"	5'-10"
Wheel diameter	36"	36"	36"
Box length, internal	48'-0"	52'	52'-3"
Box length, external	varies slightly	varies slightly	varies slightly
Box width, internal	9'-11"	9'-11"	9'-9"
Box height from top of rail (Sill Height)	varies 11' to 12'	varies to 13'-0"	varies to 11'-10"
Light (tare) weight (approx.)	54,000 lb	varies 42,000 to 45,000 lb	varies 56,000 to 59,800 lb
Maximum gross weight	263,000 lb	263,000 lb	262,500 lb

*Note: As published in Reference 9 (1982).

to procede through a mine load-out facility around a continuous rail loop. Not all mines employ a rail loop, certain operators load their trains on sidings parallel to the main rail lines. Cars are normally pulled through a load-out by the diesel prime movers.

To unload coal cars at the end terminals, the coal industry in western Canada employs the rotary dumping technique. The cars in unit coal train service are fitted with rotary couplings for use with rotary dumpers.

In 1982 there were three coal terminals on the west coast of Canada, all three were in Vancouver, and all employed rotary dumpers. Two of the three terminals, Roberts Bank and Neptune Terminals, have continous rail loops and automatic car-indexing to move trains through their dumpers. At the third terminal, Port Moody, the unit trains are uncoupled and the coal cars shunted in groups into the dumper. A new coal terminal on Ridley Island near Prince Rupert, British Columbia began operations in late 1983 and should be at or near full capacity in 1984. A rail loop, tandem rotary-dumper, thaw shed and car-indexing system are employed at this terminal.

The coal terminal at Thunder Bay, Ontario also employs a rail loop, a thaw shed, a rotary dumper and an automatic car-indexing system.

Under ideal conditions the round trip travelling time for a unit train to cover approximately 2200 kms (1400 miles) from the southern B.C. coal fields to the west coast

and back is 72 hours. The loading and unloading operations at either end add between three to four hours each to that round trip time for a total (again under ideal conditions) of approximately 80 hours. Under normal operating conditions however, delays, either during loading, unloading or en route, considerably lengthen the round trip time. Two of the Pacific coast coal terminals now employ tandem car dumpers. These double-dumping units should halve unit train unloading times at these two terminals.

3.2 Coal Production and Transportation Routes

In 1983 total Canadian coal production was approximately 44 million tonnes of clean coal (and lignite). Predictions as to the future production of clean coal in Canada vary, but even though estimates differ greatly, the general consensus is that production and exports will increase over the long term (Table 4). As a result of this expanded production and export the amount of coal shipped by rail by unit train over long distances will also increase significantly.

Except for coal imported by ship from ports on the American side of Lake Erie most of the coal presently moved over long distance in Canada is moved by rail in unit trains and the greatest portion of the coal shipped by rail for export is mined in western Canada either in British Columbia (Areas 1 and 3 in Figure 1) or in northwest Alberta (Area 2 in Figure 1). The coal shipped to Vancouver from these open pit and underground mines along the British Columbia-Alberta border is transported in open-topped rail cars by unit train over rough terrain for approximately 1 000 km.

Although coal has been shipped over the main rail lines through the Fraser Valley to Vancouver for decades, the quantity transported increased markedly with the opening of the Roberts Bank coal terminal in Vancouver in 1970. By 1981 over 1400 unit trains carried approximately 14 millon tonnes of coal through southern B.C. to the three Vancouver Coal terminals, Roberts Bank, Neptune Terminals and Port Moody.

Coal is also carried by unit train from mines along the B.C./Alberta border to the Thunder Bay coal terminal through communities in Alberta, Saskatchewan, Manitoba, and Ontario (Figure 1); however, the volume of coal moved through these areas is considerably less than the amount shipped through the Fraser Valley. Approximately 2.5 million tonnes were hauled east by over 250 unit trains in 1981. The greater portion of the coal shipped east along this route was transhipped to lake vessels for transport to Ontario steel mills and power plants.

Unit trains also haul coal from sub-bituminous mines in Alberta, lignite mines in Saskatchewan, and bituminous mines in New Brunswick and Nova Scotia. In 1981, the

TABLE 4 CANADIAN COAL PRODUCTION
(Metallurgical plus Thermal Coal)

Tonnes x 10^6				
1979	1982	1983	1990*	2000*
35	42.8	44.3	59 to 140	92 to 182

* Sources of production estimates are references 19, 20 and 21.

larger rail shipments in these areas included over 0.3 million tonnes transported approximately 400 km for the Minto to Dalhousie in New Brunswick, and approximately 0.3 million tonnes of lignite transported over 1 000 km from the Estevan area of Saskatchewan to Thunder Bay, Ontario. Most of the larger volume coal shipments in Nova Scotia are by rail over short distances.

In addition to the aforementioned coal transportation networks a major coal development located in the northeast of British Columbia has just come on-line (Area 3 in Figure 1). Coal is shipped by unit train from mines in this area to the new coal terminal at Prince Rupert, B.C. (Area 4 in Figure 1). The Prince Rupert (Ridley Island) terminal has an initial design capacity of 12 million tonnes throughput and coal shipments in 1984 are expected to reach 6.5 million tonnes.

The discussions in this report concern large coal operations which transport their product by unit train, however, it is recognized that the movement of small quantities of coal by truck, train, conveyor or barge, over short distances, may also result in local nuisance pollution from wind-blown coal dust. Although not directly applicable, the information in this document and the listed references may be of use to small producers addressing these coal dusting problems.

3.3 Emissions of Fugitive Dust and Potential Coal Losses

Almost all of the coal shipped through the lower Fraser Valley to Vancouver is processed in coal wash plants and all but a small percentage, less than 5%, is thermally dried to reduce the moisture content prior to transport. This export coal is highly friable and has a high percentage of fines, 20% less than 60 mesh (250 micron) plus 7% less than 200 mesh (75 micron) in some samples. (Ref. 22). The quantity of fine coal present in bulk coal shipments is important because loose, exposed, fine coal on or near the surface of an open-topped car can become entrained in over-the-surface winds and be carried from the car.

It is difficult to establish an emission formula for coal dust loss from an open-topped rail car because of the many variables which can effect the emission rate. Some parameters can be measured such as car geometry, route length, coal fines content and coal moisture content, but others, which include the ambient weather conditions and the state of the coal surface en route, are difficult both to predict and to measure.

Prevailing wind and the air movement created by train motion are critical to the coal dust emission rate, since they combine to create complex air flow patterns over the coal surface on the top of a rail car which can entrain exposed fine coal particles. Field observations have shown that trains travelling at speeds in excess of 50 km/h (30 mph) in dry weather will emit significantly more fine coal dust than trains travelling at lower speeds (Ref. 23). Laboratory wind tunnel tests measured threshold dusting velocities in a range of 30 to 40 km/h (18 to 25 mph) (Ref. 11), similar threshold velocities were measured by other investigators using coal from the U.S.A. (Ref. 24).

Under actual operating situations environmental parameters other than wind can also act either to mitigate or to increase coal dust emissions. For example, a train travelling at 100 km/h (60 mph) during a heavy rain storm will likely emit no visible coal dust while trains travelling at 30 km/h on a dry day, in high crosswinds have been observed to emit a "heavy" visible coal dust cloud. (Ref. 10).

Several investigators attempted to measure coal loss from trains by weighing loaded cars before and after shipment. To date, all of these efforts have been unsuccessful (Refs. 1, 3 and 25). The following excerpt (Ref. 3) is a description of the difficulties encountered during one experiment: "Exact measurements of coal losses during transportation were difficult to determine with a high degree of confidence. Some problems experienced during the study included inconsistencies in weigh-scale calibration, variations of existing moisture content of the coal, addition of flying debris deposited in cars en route, and the inclusions of rain and/or snow."

However, various researchers have estimated coal losses, for a one way trip of 1 100km (approximately 700 mi) over rough terrain during dry conditions, to be in a range from 0.5 to 3% of the total coal load for a train using no dust-emission control system (Refs. 2 and 24). Measured coal losses from various coal car models in a wind tunnel were within a range 0.9% to 1.76% of the coal load, i.e. within the same range as the emission factor estimates. (Ref. 11).

The theoretical product losses which could have occurred while shipping the 1981 production of 14 million tonnes of coal to Vancouver, if no dust control systems were in place, are listed in Table 5. Three dust loss factors were used in order to reflect the

many uncertainties with respect to dust losses. It is evident that even at the low end of the emission range, 0.25% dust loss, there is a potentially significant product loss. This loss of product provides an economic incentive for companies to control wind-blown coal losses from their unit trains.

However, these estimates represent potential maximum uncontrolled emissions whereas all of the major producers shipping coal to Vancouver in 1981 employed sealant sprays to control coal dust emissions. The level to which the dust emissions from these trains were reduced by the surface coatings provided by these sealant sprays has not been quantified. However, for purposes of illustration of the impact of dust control, a direct linear relationship between the percent surface coating-remaining on a coal car at the end terminal and the percent reduction in coal dust emissions en route was assumed and the estimated losses revised to reflect an assumed 85% dust control, achieved by an assumed 85% average crust-retention on all coal trains, Table 6. A comparison of Tables 5 and 6 illustrates that the coal mining companies can save a considerable amount of potentially lost revenue by limiting the loss of saleable product.

3.4 Coal Dust as a Nuisance Contaminant

The dust emitted by a unit coal train is comprised mainly of fine black coal particles which are carried by winds onto properties adjoining the railway tracks. This fine black dust will soil almost any exposed surface, adversely affecting the aesthetic appearance of property and clothing. Coal dust soiling complaints concern damage to curtains, drapes, decks, automobiles, lawn furniture, clothing, boats and cars. The complaints from citizens have been directed to their elected representatives, government agencies, railway companies, coal mining companies and to local newspapers (Ref. 2).

In addition to residential nuisance soiling there is a potential for the cross-contamination of industrial products by wind-blown coal dust from unit trains. During the early planning stages of the recently completed northeast B.C. coal development operators of a pulp mill adjacent to the site of the Ridley Island, Prince Rupert coal terminal expressed concern about potential contamination of their pulp product by wind-blown coal dust from terminal activities and the operation of unit coal trains which would pass their property. The pulp mill operator's concerns were recognized and mitigation measures were installed as an integral part of the northeast B.C. coal development. (Ref. 15).

Another minor problem associated with coal dust blown from trains is eye irritation. Since 1979, Environment Canada observers in Agassiz, B.C. have reported 13

TABLE 5 THEORETICAL LOSS ESTIMATES - UNCONTROLLED EMISSIONS

Uncontrolled Emission factor	Losses for a 100 car unit train		Potential losses for 14 million tonnes of coal shipped through Vancouver (1981)	
(% of load)	Coal Lost (tonnes)	Economic Loss (at $70/tonne)	Coal Lost (tonnes)	Economic Loss (at $70/tonne)
0.25	25	$1 750	35,000	$2.45 x 10^6
0.5	50	$3 500	70,000	$4.9 x 10^6
1.0	100	$7 000	140,000	$9.8 x 10^6

TABLE 6 THEORETICAL LOSSES - 85% CONTROL OF COAL DUST EMISSIONS

Uncontrolled Emission Factor	Losses for a 100 car unit train with 85% Dust Control		Potential losses for 14 million tonnes of coal shipped through Vancouver (1981) with 85% Dust Control -	
(% of load)	Coal Lost (tonnes)	Economic Loss (at $70/tonne)	Coal Lost (tonnes)	Economic Loss (at $70/tonne)
0.25	3.75	$ 263	5 250	$ 367 500
0.5	7.5	$ 525	10 500	$ 735 000
1.0	15	$1050	21 000	$1 470 000

separate incidents of noticeable eye irritation while watching dusting coal trains (Ref. 4). This irritation is temporary and apparently has no long term adverse effects.

Coal dust blown from trains is a nuisance pollutant and is not considered to be a hazard to human health. Long exposure to very high levels of airborne coal dust in coal mines is known to cause pneumoconiosis (black lung) in coal miners (the threshold limit value, TLV, the maximum allowable exposure for workers for 8 hours or a 40 hour week for coal dust, is 2000 $\mu gm/m^3$), but citizens residing in the vicinity of railway tracks are exposed to much lower levels. For example, the total suspended particulate measurements from a provincial air monitoring station 100 meters from the railway tracks in Agassiz, B.C. have been below the annual maximum "acceptable" standard of 70 $\mu gm/m^3$ since 1979.

Although airborne coal dust concentrations in the vicinity of the railway tracks during the passing of a "heavily" dusting train can be high, the emission incidents are brief, six to 10 minutes. The hazard to human health of repeated exposure to high level, short duration dusting events is not known.

In an effort to determine more about the effect of coal dust on biological systems, Environment Canada commissioned a study to test four Canadian coal samples for possible mutagenic activity. The results of the study (Ref. 7), and another similar study in the U.S.A. (Ref. 26), were inconclusive. Fugitive coal dust from unit trains is still considered to be a nuisance contaminant.

With respect to government legislation, there is no federal or provincial standard which applies specifically to the short-duration nuisance pollution incidents associated with wind-blown coal dust from unit trains. The existing air quality objectives developed for particulate matter by these two levels of government apply to total suspended particulates or total dustfall (some provincial governments only) without regard to its composition or source.

3.5 Pathways

The air currents over the surface of the coal load in a rail car are a combination of ambient wind and wind generated as a result of train motion. Field observations confirm that only one wind component is required in order to entrain coal and generate a nuisance dust cloud, i.e. a stationary train subject to ambient wind or a moving train on a calm day.

The deposition distance for coal particles blown from unit trains will depend upon a variety of factors such as: coal car height, train speed, prevailing ambient

conditions, terrain obstructions, plus the properties and size of the coal particles. Visible coal dust was reported by one observer (Ref. 23) to carry at least 30 metres from the centre of the tracks. The Environment Canada coal dust monitoring station at Agassiz, B.C. has dust samplers located up to 50 metres from the centre of the railway tracks, and evidence of coal dust deposition has been found at those locations (Ref. 4).

A study (Ref. 6), commissioned by the Roberts Bank (BC) Expansion Railway Committee, reporting on the results of rail-side dust monitoring studies found that, "... the major (dust) impacts from present rail operations are likely to be contained within a zone of 150 metres on either side of the tracks," and ".. that most, if not all, of the coal dust falls out within 160 metres of the tracks". Based upon experience in western Canada it would appear that the area of primary exposure to wind-blown nuisance coal dust from unit trains is within 200 meters of the railway tracks. Homes at west end of Agassiz and in other communities in southern British Columbia are located within 40 metres of the railway tracks.

Secondary transport of settled coal dust can occur either as a result of reentrainment by ambient wind or direct contact (e.g. on the soles of shoes). The action of either of these transport mechanisms can result in nuisance coal dust being carried beyond the original impact site.

3.6 Exposure - Public, Industrial

Hundreds of private homes along the rail corridor from the coal fields of southeast B.C. to Vancouver are located within 200 metres of the tracks where coal trains pass through over thirty small communities and settlements. Since 1970 complaints about fugitive dusting from unit trains have been received from a number of communities including: Cranbrook, Kamloops, Agassiz, Delta, and Surrey.

The area from Hope to Vancouver appears particularly prone to fugitive dusting. This section of the rail line is near the end of the long coal-rail journey from mine to terminal and many of the surface sealing coatings on loaded rail cars have fractured or broken as a result of vibration and shock experienced en route. Much of the terrain along this section of the route is also flat and trains frequently travel at or near the maximum allowable track speed (80 km/h). High natural crosswinds frequently combine with train generated winds to create high, turbulent, dust-entraining air currents over coal cars.

The recently opened coal/rail corridor in northern B.C. from Tumbler Ridge to Prince Rupert not only passes through many small communities, but it also passes by

several pulp and paper operations. The sensitivity of certain pulp and paper operations to possible product contamination by wind-blown coal dust from unit coal trains was first addressed in connection with the Ridley Island coal terminal construction. (Ref. 15). Recognizing the potential for both cross-contamination of industrial products and residential nuisance pollution as a result of this coal movement, the Northeast Coal Technical Committee on Coal Dust was established to address possible dusting problems from trains using this route. Before the first coal shipments began in late 1983 the Committee had instituted a background dust monitoring study to collect total suspended particles at 15 sites along the corridor. Comparisons of dust measurements made before and after the start of coal train traffic will provide a means of assessing exposure to coal dust emissions.

Although only a limited number of industrial facilities are likely to fall within the range of possible exposure to fugitive coal dust contamination from unit trains, the impact is important because of the negative economic implications involved.

As shown in Figure 1, coal is transported by rail through small communities in provinces other than British Columbia, however because there has been little or no public concern registered with respect to these shipments, British Columbia is considered the principal area of population exposure to this form of nuisance air pollution.

3.7 Coal Dust Sampling and Analytical Methods

In order to assess the extent, severity and persistance of an air contaminant it is desirable to measure emissions both at the source and at the point impact. In this case however, because the source is 100 moving, 46 m^2, open rail-cars possibly emitting dust over an entire 1000 km journey, particulate collection at the source is impractical. The alternative is to measure coal dust emissions from unit trains at the point of impact.

3.7.1 Particulate Sampling. Two types of point-of-impact particulate sampling are required, episode and long term. Episode monitoring, the collection of coal dust from single trains, is necessary in order to evaluate the performance of specific test trains or to record the effectiveness of the dust control measures employed by a specific coal mine. Long term monitoring is required in order to evaluate overall trends in nuisance dusting.

The dust emissions from a moving train when viewed from a fixed sampling point are of high intensity and last only a few minutes. These unique characteristics present problems when using conventional particulate sampling devices.

A. Long-Term Trend Monitoring

Investigators have experimented with a variety of conventional sampling methods for rail-side long-term trend-monitoring including high-volume, low-volume, soiling index and dustfall samplers (Refs. 4, 5, 6, 10, 12, 18). Optical particulate counters have also been employed (Refs. 12 and 16). None of these devices has fulfilled all of the requirements of a monitoring system for measuring long-term trends for coal dust from unit trains.

The standard dustfall monitor can, and is, used for trend monitoring but it lacks versatility. The long sampling interval, approximately one month, limits its application. Dustfall jars have been used for trend monitoring at the Environment Canada Agassiz monitoring site. (Ref. 4).

There has been a renewed interest in the conventional soiling index device (the COH tape sampler) as a trend monitoring instrument. The British Columbia Ministry of the Environment is conducting field experiments with this particulate sampling instrument (Ref. 12).

Low-volume samplers were field tested by both the British Columbia Ministry of the Environment and Environment Canada (Ref 12), however, for this application the device suffers from a low sampling rate which limits the quantity of particulate it can collect during a brief dusting event.

The conventional high-volume sampler is still under evaluation as a method of measuring trends. (Ref. 12). However, the high-volume sampler has its highest collection efficiency for particles of less than 30 microns, and therefore, since one investigator has reported that between 93 and 95%, by weight, of the particulate collected from loaded coal trains (using the coated-plate technique) was greater than 20 micron in diameter (Ref. 6), the approximately 30 micron cut-off of the conventional high-volume sampler would probably exclude from capture much of the coal particulate which would contribute to nuisance soiling. Also, the high-volume sampler integrates particulate collection over a 24 hour period and masks the short duration, individual dusting events.

B. Short-Term Episode Monitoring

Most conventional ambient-particulate collection devices also appear unsuited for short duration episode or event monitoring applications. For example, experiments have shown that when used in its standard configuration for short episode monitoring the high-volume sampler suffers from an inability to collect sufficient particulate mass and,

as in the trend monitoring case, the approximately 30 micron upper cut-off appears to restrict from capture the large coal particles which could still contribute to nuisance soiling.

The conventional dustfall sampler captures all settleable particles and does not screen out the larger particles, but this device is designed to collect settleable particulate over a one month exposure period and does not have sufficient open surface area to collect a measureable coal dust mass during individual, short duration, train dusting events.

However, several experimental particulate collection systems have proved successful in monitoring individual short term nuisance dust pollution events. The devices or methods tested include: a series of coated horizontal plate collectors (Refs. 6, 10 and 27), and a modified high-volume sampler (Ref. 4). Both of these devices appear to be capable of collecting sufficient particulate matter from a single dusting event, but unfortunately both these techniques are labour intensive and require an operator on-site during each event to be measured.

Aerosol monitors employing the light scattering technique have been tested for episode monitoring (Refs. 12 and 16). These devices do not require an on-site operator, but they do not collect a particulate sample for analysis and light scattering instruments are typically insensitive to particles larger than 20 micron in diameter (Ref. 16). These limitations restrict the application of these devices for coal train dust monitoring.

3.7.1.1 **Settleable particulate monitoring results.** As noted above, standard dustfall monitors have been employed at the Environment Canada Agassiz monitoring site since 1979. The dustfall measurements cannot be correlated to the visual observations recorded at the same site (Table 1), because the visual observations are not a complete history of all of the coal trains passing through Agassiz, however, a comparison can be made to provincial, ambient dustfall standards.

Environment Canada does not have an ambient particulate standard for dustfall, but the Province of British Columbia employs a dustfall objective of 1.7 to 2.9 mg/(dm^2. day). The number of gravimetric readings from the four Environment Canada dustfall monitors at Agassiz which exceed the maximum provincial standard of 2.9 mg (dm^2. day) are presented in Table 7. (Ref. 4).

The four dustfall monitors operated by Environment Canada are close to the railway tracks (within 50 m), therefore, coal dust from unit trains would appear to be a major contributing factor to the high dustfall levels measured at the trackside monitoring

TABLE 7 AGASSIZ DUSTFALL READINGS COMPARED TO B.C. STANDARD

Dustfall Monitor	Sept. 79 to Apr. 83 Total Readings	Number of Dustfall Readings Which are			
		Below 1.7	Within 1.7 to 2.9 Range	Above 2.9	Percent Above 2.9
N1	30	14	6	10	33
N2	27	13	6	8	30
S1	27	12	7	8	30
S2	27	7	9	11	41
Number of Readings	111	46	28	37	33%

* The B.C. Provincial objective for total dustfall is 1.7 to 2.9 mg/(dm^2·day).
N1 = 18.6 meters north of the tracks. S1 = 24 meters south of the tracks.
N2 = 41.8 meters north of the tracks. S2 = 50 meters south of the tracks.

locations. However, the frequent occurrence of dustfall levels greater than 2.9 mg/(dm^2·day) cannot be confirmed as originating primarily from trains without an accurate method of analyzing for coal dust.

3.7.2 Coal Analysis. Conventional particulate samplers collect all of the particulate matter in a certain size range and therefore simple gravimetric analysis alone will not quantify particulate loading due to coal dust. The coal fraction of collected particulate samples is required in order to accurately assess coal dust impacts, particularly when samples have been collected over longer sampling intervals. Recent developments (Ref. 12) in analytical methods show some promise with respect to measuring the amount of coal in collected samples. A research project is underway, sponsored jointly by the B.C. Ministry of Environment and Environment Canada, to evaluate several of these new methods. The ongoing evaluation may provide a method which can be used to apportion the sources of the particulate in collected trackside dustfall samples. (Ref. 12).

A satisfactory method for quantifying coal in collected dust samples is necessary before coal dust impacts can be measured in proper scientific terms. A scientific assessment of the effectiveness of dust-control measures also requires a proven coal analysis method.

3.8 Performance Assessment

Coal dust from unit trains is a nuisance pollution problem and as such subjective judgement is necessary in order to assess acceptable levels of nuisance. Establishing a coal dust collection method and an acceptable coal quantification technique will simplify the assessment process, but a certain degree of subjective assessment of nuisance levels will still be required. This requirement for subjective judgement makes it difficult to establish air quality criteria or to prescribe specific dust emission performance levels for coal trains.

At present, two methods are used to assess levels of fugitive dusting and the performance of dust-control systems, the measurement of surface coating-remaining (or crust-retention) at the end terminal and the observation of visible dust emissions from individual trains. It is likely that these two techniques (discussed below) will continue to be used for at least the near future.

3.8.1 Crust-retention Measurements. Lacking proven quantitative sampling and analytical methods for coal dust, the initial investigators (Ref. 2) moved away from a performance measurement approach that relied on ambient air sampling techniques to one that relied on measuring the percentage of the coal surface of loaded cars arriving at the unloading terminal still covered by a dust-sealing surface-coating (as sprayed at the coal mines). It was generally agreed that when more crust was retained over the surface of the load there ought to be a corresponding reduction in coal dust losses en route and hence, better control of wind-blown dust.

A crust-retention goal of 85% coverage, when measured at the unloading terminal, was arbitrarily selected and agreed to by the industry (Ref. 2). The industry/government studies carried out in the early 1970's had concluded that 85% crust-retention was achievable at that time. It was also felt that 90% crust-retention could be achieved by October, 1975 and that crust-retentions approaching 100% could be expected by the end of the 1970's (Ref. 2). The attainment of coating-retention averages of close to 100% would have meant the virtual elimination of fugitive coal dust emissions.

Regardless of the crust-retention goal, there is a danger when employing this technique since the lack of proven ambient coal dust sampling and analytical methods precludes verification of the degree of dust control. Improvements in crust-retention cannot be correlated to corresponding reductions in measured ambient particulate levels at en route locations, i.e. does 85% crust-retention mean that fugitive dust emissions have been cut back by 85%.

Another drawback to this technique of performance assessment is that crust-retention measurements are time consuming and manpower intensive. Personnel are required at the unloading terminal to observe, estimate, and record crust performance. Also, individual train crust-retention assessments usually result from averaging the crust-retentions measured on less than 20% of the cars (15 to 20 cars) within a particular train.

However, in spite of these limitations, until an alternative technique is developed, the crust-retention method will continue as the means of assessing control-system performance.

3.8.2 Results: Crust-Retention Studies. In 1981, Environment Canada personnel observed a small number of unit trains at two Vancouver coal terminals and found that the 85% crust-retention goal was not achieved on the trains assessed (Ref. 18).

Subsequently, in 1982, in order to assess the performance of the existing dust control systems and to attempt to establish reasons for the persistence of fugitive dust emissions from unit coal trains, Environment Canada, in conjunction with the Province of British Columbia and with the cooperation of the coal industry, commissioned a more extensive coal train study. The surface coatings-remaining on over 1300 coal cars in 47 unit trains (as they arrived at either of two coal terminals in Vancouver) were examined by observers and the results reported with respect to the percentage of the top surface of each of these cars still covered by dust suppressant crust. The unit trains examined originated from four coal mines, two in northwest Alberta and two in southeast B.C. The results of this coal car survey, illustrated in Tables 8 and 9, also indicated that the over-all crust retention averages for the trains examined were less than the 85% goal. (Ref. 10).

During the period of this study (September to November 1982), for the cars assessed in the unit trains inspected, only 24% (11 of 47 trains) revealed crust-retention averages equal to or greater than the 85% unofficial crust-retention goal. The total overall crust-retention averages for the trains from each mine were all below the 85% goal, Table 8. These results support the evidence of the earlier field work in August of 1981 (Ref. 18).

A re-evaluation of the raw data from the crust-retention study expressed the overall performance for each train from each mine as the percentage of the coal surface exposed or uncovered at the end terminal and confirmed that the 85% crust-retention goal was not achieved on the trains examined. (Ref. 28).

The range of crust-retention averages measured during the study is a reflection of the lack of consistency of dust control-system performance. With the

TABLE 8 CRUST-RETENTION PERFORMANCE BY COAL MINE

Mine	No. of cars	Coverage-Retention Averages (%)				
		F*	C*	R*	Total	Range
A	120	51	98	42	81	78 to 83
B	348	49	88	36	78	36 to 95
C	446	72	94	20	77	50 to 89
D	460	51	94	27	75	55 to 98

* F - Car Front

* C - Car Centre

* R - Car Rear

Note: All trains were sprayed with latex-based products.

TABLE 9 CRUST-RETENTION - 85% GOAL

Mine	Number of Trains Examined (N)	Crust-Retention		Number of Trains		
		Average "N" Trains (%)	Range (%)	≤ 75%	75% to 85%	≥ 85%
A	4	81	78 to 83	0	4	0
B	12	78	36 to 95	4	3	5
C	16	77	50 to 89	6	7	3
D	15	75	55 to 98	9	3	3

exception of mine A (where only four trains were available for inspection during the trial period), the three remaining mines registered a number of "very good" trains, with projected average coverages greater than 85%, but each mine also registered an equal or greater number of "poor" trains, assessed at less than 75% average crust-retention. For example, Mine B had five trains assessed at greater than 85% average crust-retention, and four trains assessed as less than 75% crust-retention. Two of the latter were assessed at less than 50% average crust-retention.

Therefore, although the existing spray systems are capable of coating trains with dust suppressant coatings which have a high crust-retention rate, on many other occasions the coatings provided by the same spray systems are inadequate for dust control purposes.

Again, note that caution must be exercised when interpreting crust-retention averages. Crust-retention measurements are made on individual coal cars examined at the end terminal, whereas average performance ratings refer to either an entire train, or to the combined averages for a number of unit trains.

Regardless, the field study results indicate that the existing chemical spray control systems fail to provide consistently high crust-retention averages. Trains with low crust-retention are the prime reason for the continued dust emissions from unit trains.

The Environment Canada field study (Ref. 10) also included the assessment of the surface coatings on over 350 coal cars sprayed with experimental sealant chemicals or formulations. The performance results for some of these new chemicals were encouraging. Subsequent to the field study several coal mines in western Canada switched to spraying chemicals other than latex.

3.9 Visual Observation of Unit Trains

An assessment of the severity of individual train dusting incidents can be made by observers recording visible dust emissions. This technique has been employed at the Agassiz monitoring station with observers classifying coal trains as either "heavy", "medium", "light", "very light", or "not" dusting (Ref. 4).

However, even though the visual observation technique provides a direct indication of the severity of train dusting, there are difficulties with respect to its application. One difficulty is the need for subjective judgement. Trains assessed as "medium" and "heavily" dusting are usually obvious even to an inexperienced observer, but differentiation between "light" and "very light" incidents can be controversial. Other problems with the technique include: the inability to assess trains travelling at night, and the apparent contradiction when trains assessed as having no visible dust emission are judged to be sources of soiling dust. The latter difficulty arises because very fine coal dust not visible to an observer may still carry from a train and settle as observable particulate.

However, experience has shown that trains assessed at the upper end of the visible dusting range, i.e. as "medium" and "heavily" dusting, are known sources of nuisance soiling. The visual detection of these trains will continue to be the most rapid method of reporting obvious cases of dust control system performance failure to the coal mining companies. The results of five years of train observations at the Agassiz monitoring site are discussed below.

3.9.1 Visible Dusting Results. Environment Canada has maintained a dust monitoring station in Agassiz, B.C. since 1979, a summary of the visual observation of unit coal trains passing that site is presented in Table 1.

It is important to note that although investigations have centered on the problem of visible dust emissions from loaded trains, each year a small number of visible dusting incidents have been recorded for "empty" trains travelling east through Agassiz. Dust emitted by "empty" trains appears to result from unemptied coal in the bottom of cars or from coal which clings to the external surfaces of a car after dumping.

For loaded coal trains, the percentage of visible dusting incidents (as compared to the total number of loaded coal trains observed) has been declining since 1979, Table 10 (Ref. 4). Although the precise reasons for this decline are not known, one possible explanation is the increased activity on the part of the Federal/Provincial governments and the coal industry with respect to wind-blown coal dust and its control.

TABLE 10 VISIBLY DUSTING COAL TRAINS - AGASSIZ

	Observed Visibly Dusting Loaded Trains	Total Observations	% Dusting
1979	73	309	24
1980	58	323	18
1981	61	459	13
1982	49	370	13
1983	39	363	11
January 1984	12	31	39

This apparent improvement with respect to the total number of visibly dusting loaded coal trains through Agassiz is encouraging, however, considering the nature of these observations, caution is advised in interpreting the results. The Agassiz monitoring station was not manned on a 24 hour basis, therefore not all of the coal trains passing the Agassiz monitoring site were observed. Each day a number of visibly dusting and non-dusting trains would not have been detected. This is especially important for trains travelling after dark since in recent years there has been a speed restriction on "heavy" dust emitting trains during daylight hours. (Refs. 4 & 23).

More importantly, although the total percentage of visible dusting trains to total trains observed has declined, the number of "medium" and "heavy" dusting trains has remained high (Table 1). "Medium" and "Heavy" visibly dusting trains are known to be sources of nuisance soiling, therefore what appears to have been an overall performance improvement for dust control systems since 1979, is marred by a lack of consistency. Major spray system breakdowns, cited by operators as the cause of unsprayed or poorly sprayed trains, continue to occur, and these breakdowns lead to "heavy" visibly dusting trains and unacceptable nuisance dusting incidents.

An illustration of inconsistencies in the performance of the existing dust control systems is revealed by the visual observation results for January, 1984 (Table 1). After what appeared to be an improvement in overall dust control and a reduction in "heavy" dusting trains incidents in 1983, a reversal occurred ir the first month of 1984. In January 1984 observers recorded the highest number of "heavy" dusting trains for any single month since inception of train observations in 1979. The percentage of visible dusting incidents to total observations for that month was also high (Table 10). In addition, the number of dusting incidents recorded for "empty" trains during January 1984 exceeded the entire number of "empty" train, visible dusting events recorded for all of 1983.

This apparent reversal in performance trends was investigated. Spray equipment malfunction, spray system freeze-up plus inexperienced personnel operating equipment at a new mine were cited by the coal producers as reasons for this high number of nuisance dusting events. Break-down of the car wash at one coal terminal was considered as one possible reason for the increase in "empty" dusting trains.

4 SPRAY DUST CONTROL SYSTEMS - OPERATIONAL PROBLEMS AND SUGGESTIONS FOR IMPROVING PERFORMANCE

The chemical spray method of dust control is the system adopted by all of major coal producers in western Canada who ship coal over long distance by unit train. In theory, sealant chemicals once applied form a solid crust or contiguous flexible layer over the surface of the coal load in a rail car thus preventing fine particle wind entrainment and hence fugitive dusting.

The facilities for applying chemical sealants, as installed at the western Canada coal mines, comprise storage tanks for the chemicals, mixing tanks or in-line mixers, pumps, valves and one or more swing-out spray headers or spray bars, (Figure 5). The tanks and pumps are located in a heated shed while the spray headers and connecting piping are located outside and are usually wrapped and heated to prevent freezing. The spray headers, which may comprise a number of separate spray bars and nozzles, are designed to pivot out of the way of engine units and other train components. Most of the mines have also installed coal profile-levelling devices as integral parts of the dust control systems.

The chemical sealant spray systems were first installed in western Canada in the mid-1970's and in the interim the coal mining companies have conducted numerous experiments with different chemical sealants, application methods and loading techniques. However, although improvements have resulted from these activities the performance of these systems has been inconsistent and unreliable. Problems inherent with this technique combined with non-standardized operation and maintenance procedures appear to be the reasons for many of the performance failures observed since widespread use of the sprays began almost ten years ago.

The chemicals sprayed over the coal surface at the coal mines frequently fail to provide or to maintain a complete crust or coating over the coal surface during the trip to the end terminal. Coal trains sprayed at a mine load-out arrive at an end terminal with many cars which have the following surface crust deficiencies: little or no crust covering the front and rear end slopes; uncovered strips up to one half a metre wide down the sides of the cars; deep uncovered gouges in the centre of the surface profile; alternating strips of covered and uncovered coal along the top of the load; or with an entire car surface uncovered. Insufficient crust-retention on steep end slopes was noted during the original tests in the early 1970's and remains the most frequently occurring problem with respect to uncovered coal surfaces (Refs. 2, 10 and 18).

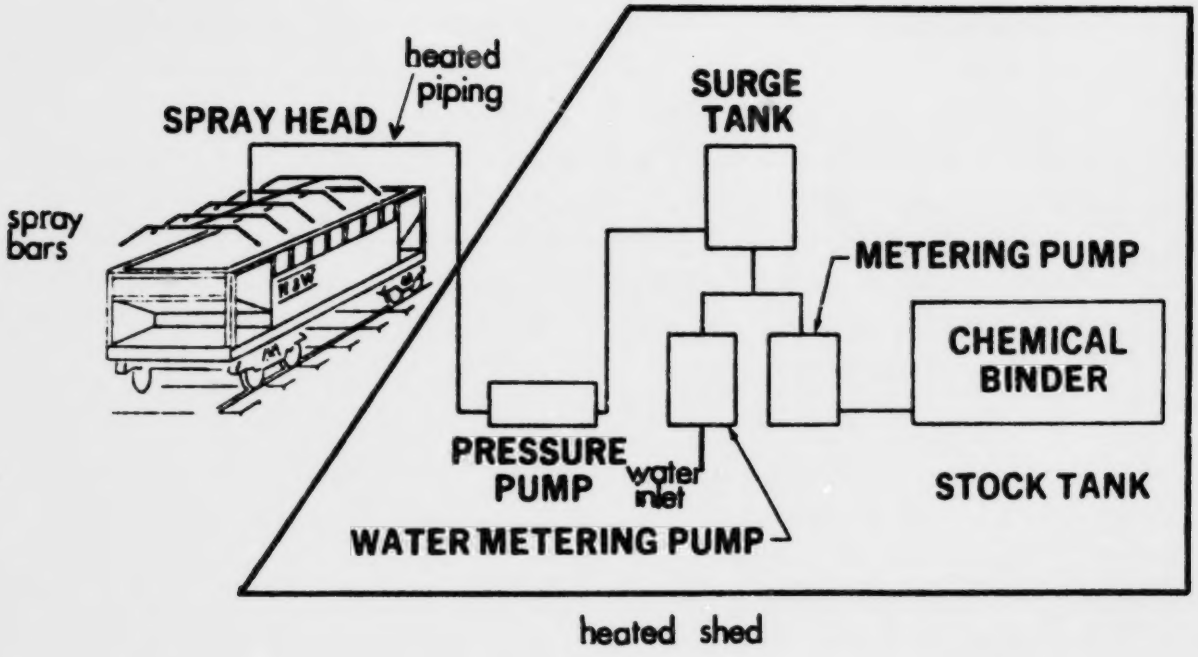


FIGURE 5 GENERALIZED SCHEMATIC OF A CHEMICAL SPRAY INSTALLATION

Observation has indicated that the frequent occurrence of exposed surfaces in coal cars which have been sprayed with sealant chemicals may result from one or more of the following factors:

- poorly designed spray apparatus which, because of incomplete mixing or incorrect spray timing, can result in incomplete coverage of a coal car surface or the uneven application of spray solutions;
- inadequate maintenance procedures at the mine site which can result in plugged or inoperative spray nozzles, incorrectly aimed spray nozzles, or total equipment malfunction;
- the application of a sealant chemical at a concentration which is insufficient for producing stable surface crusts for the ambient conditions at the time of shipment;
- the selection and use of a sealant chemical product which is incapable of producing a crust or surface coating which will withstand the rigors of the journey;
- insufficient operator training which results in operator error and unsprayed surfaces;
- weaknesses inherent in the sealant chemical spray technique; or
- an inadequate load-levelling device.

In spite of these problems, because the application equipment, the trained personnel, the chemical storage, and the chemical distribution networks are in place and in operation at most of the major coal mines in western Canada, this method of dust control is likely to remain the industry preferred dust abatement technique in western Canada for at least the foreseeable future.

Although further research is required to discover the optimum operating parameters for many of these systems, observation and experiment to date have shown that changes can be made which should result in overall performance improvements. The problem areas and suggested improvements are discussed in the following sections.

4.1 Chemical Sealants

The physical-chemical characteristics of a chemical sealant such as: wetting characteristics, phase separation and viscosity can determine a chemical's ability to form a stable crust or coating over the coal loaded in a rail car.

Dry coal exhibits a poor affinity for water, therefore manufacturers normally add surface active agents to their products to improve their wetting characteristics and surface penetration. Laboratory and field tests have shown that most sealants do not adhere to sloped surfaces as well as they do to flat surfaces and one explanation for this

failure is related in part to the wetting characteristics of the sprays (and to the simple fact that the solution will run off steep slopes). Oil and oil-based sealants have demonstrated good surface penetration on both flat and sloped surfaces.

Products with inferior mixing/emulsifying chacteristics periodically cause phase separation problems which can result in poor quality crusts by delivering inconsistent solution concentration at the point of application. Variations in spray solution concentration throughout a batch can result in surface crusts of varying strength throughout a single unit train, therefore thorough mixing of spray solutions is essential.

The flow properties of a spray solution or emulsion are affected by the viscosity characteristics of the chemical sealant. Increased viscosity at below freezing temperatures can result in frequent plugging of the spray nozzles on the application headers. Difficulties with nozzle plugging have been reported for both asphalt-based and latex-based sprays.

One asphalt-based sealant was unacceptable to the railway company hauling the coal because the viscous emulsion caused excessive fouling of the rail car exteriors and hydraulic components.

The first comprehensive series of tests and observations of spray system performance were conducted in 1974. The tests, described in Reference 2, were joint studies carried out by federal and provincial environment agencies and the railway companies with the cooperation of several of the large coal producers. Eight chemicals were evaluated during those tests and their performances were assessed using the crust-retention technique. Of the chemicals tested oil and oil-based emulsions were judged the most effective because of their crust regenerative properties, while latex type binders were only as effective as oil emulsions when sprayed on horizontal, flat surfaces.

However, none of the chemicals tested provided a crust that would stay intact and cover 100% of the coal surface on every car for the entire journey from coal mine to end terminal. A lesser crust-retention goal of 85% was agreed to by the coal mining companies as the initial target but investigators predicted that once new sealants, application techniques, and loading methods were perfected, crust-retention averages of 95% and higher would be achieved (Ref. 2).

As discussed in Section 3.8.2, these high crust-retention averages have not been achieved and since 1975, in attempts to improve dust suppressaht performance and to optimize costs, coal shippers have experimented with and in some cases switched to new chemicals or new formulations of older products.

In the summer of 1980, only two types of chemical sealants, asphalt and latex emulsions, were in regular use, and by July 1981, the one firm spraying the asphalt emulsion switched to a latex spray. From August, 1981 to January, 1983, latex-based chemical sealants were the only type of chemical spray employed by the western Canada coal mines on a regular basis. In 1983, in search of more effective chemicals, several coal shippers shifted away from latex products and began using or experimenting with asphalt-based or polyacrylamide products. A list of many of the products which have been used, or tested, as dust suppressants is presented in Appendix B. (Ref. 30).

In 1981, because of the predominance of latex-based sprays and the continuing performance problems with those products, Environment Canada commissioned a study to evaluate latex spray performance. Because of the high cost of full scale, in-situ testing, the experiments were performed in a laboratory. The results of those tests confirmed several known or suspected adverse traits of latex-based sprays (Ref. 8):

- latex spray crusts do not adhere to slopes or irregular surfaces as well as they do to flat surfaces;
- to achieve maximum success on a sloped or irregular surface the entire surface must be coated with spray. Partially coated surfaces will produce partial crusts and partial crusts, particularly on a steep slope, are easily undermined. Undermined crusts will fail and an uncovered surface will result;
- the length of time a crust has to cure and the ambient conditions during the curing period will influence crust strength;
- latex sprays normally form brittle crusts which are severely damaged by shocks and vibrations of the magnitude experienced within a coal car en route; and
- the concentration of the applied emulsion will influence crust performance.

The inability of latex-based and other dust suppressant products to produce crusts that will adhere to steep end-slopes in loaded cars has been reported by almost every researcher who has investigated surface coating performance (Refs. 2, 8, 10 and 18). However, in spite of ten years experience using chemical sprays, a practical solution to the end-slope retention problem has not been found.

The weathering of surface coatings en route is also a problem. Unit trains operate all year round and during the coal mine to end terminal section of a round trip cycle the surface of the coal loaded in a car (and therefore the dust suppressant surface coating) will be subjected to the prevailing ambient conditions for a minimum of 36 to 40 hours. Frequently, because of delays, loaded coal trains are stationary and subjected to

weathering for many hours before proceeding on the next part of their journey. Degradation of a surface coating as a result of ambient weathering can reduce the dust abatement effectiveness of the coating.

The effect of weathering on surface coatings was demonstrated during a recent performance evaluation (Ref. 10). For ten of the twelve trains originating from Mine B the lowest recorded crust-retention was 71%; however the crust-retention averages for the other two trains from that mine were 36 and 44%. One explanation for this drastic difference was that the two trains with the low crust-retention averages had been held on sidings in the B.C. interior subject to weathering for about three weeks prior to completing their journey. This prolonged weathering could have been the major cause of crust destruction.

New dust suppressant products which may be capable of overcoming some of the problems noted above are under test. Some of the preliminary results for new chemicals are encouraging, however incidents of "heavy" dusting trains continue in spite of their use. However, the failure of spray dust-control systems to achieve more consistent and more complete dust abatement cannot be attributed solely to the inherent weakness of the sealant chemicals, other parameters also influence sealant spray performance. These factors are discussed in the ensuing sections.

4.1.1 Spray Solution Volume and Concentration. The concentration of the chemicals as applied to coal surfaces will influence the performance of surface coatings, although, the exact relationship between spray concentration and crust-retention under operating conditions is unclear. For most dust suppressant products the crust formed by a 20% solution will be stronger than the crust produced by a 5% solution. However, the cost-effectiveness of the technique is questionable, since the evidence to support significantly improved overall crust-retention as a result of applying a higher concentration spray is limited. Other factors may have a greater influence on crust-retention performance, i.e. more concentrated solutions may not significantly increase crust-retention performance unless accompanied by improved application techniques and improved load-levelling.

Since the spring of 1982, the coal mining companies in British Columbia that ship coal through Vancouver have supplied Environment Canada with details on both the concentration and quantity of sealant solution applied to each of their trains. These records confirm that both the quantity and the concentration of the spray solutions applied at each mine can vary widely from month to month and often from train to train. Variation in solution concentration could account for some of the spray system performance inconsistencies observed at the Agassiz monitoring station.

Field observations (Ref. 10) have indicated that the spray facilities at each mine are different and some do not appear capable of the complete solution mixing and the uniform spray chemical application rates that are required to produce a uniform, stable crust on every car. To ensure that an equal quantity of uniformly mixed solution or emulsion at the desired concentration is applied to each car in every unit train, each mine load-out spray installation should have an accurate mixing and flow-metering system capable of delivering equal volumes of sealant solution of uniform concentration to each car (Ref. 10).

The irregular movement of a train through a spray facility has also been observed to cause problems with respect to the application of uniform volumes of spray to each car. Train speed during loading can vary and stops are frequent. Many spray facilities are not capable of adjusting to these differences and therefore certain cars receive too much spray while others don't receive enough. One recommendation from the Environment Canada sponsored survey of spray facilities (Ref. 10) was that operators should investigate measures to spray constant volumes of sealant solution per car regardless of train speed.

4.1.2 Application Techniques. There is no standard application technique for chemical sealants. Although the basic principle of mixing a commercial strength chemical with water and spraying the resulting solution or emulsion on a loaded coal car is adhered to at all mines, the number of spray headers, the number of nozzles, their location, and the height of the headers will vary. Some mines use only a single spray header while others employ a series of consecutive spray headers (up to 5 at one site). Although the number of spray headers and the number of nozzles per bar may not be critical, a system designed to provide a thorough, even distribution of the spray fluid over the entire coal surface in a loaded car is essential.

Incomplete spray coverage of both the end slopes and the edges of loaded cars has been observed and proposed as a reason for crust break-up and poor crust-retention performance (Refs. 8, 10 and 23). Coal shippers should inspect their spray facilities and ensure that chemicals are being applied in the most efficient manner. Improved spray applicator design may be required.

Certain spray facilities employ multiple headers and spray cars alternately with chemical sprays and water-only sprays as the cars proceed through a spray installation. One reason for using the water flush or water-only spray is based on a theory that a water spray applied after a coating of a dust suppressant chemical will drive or

carry the sealant forming chemical deeper into the coal surface thereby providing a thicker crust.

The effectiveness of post-sealant, water-only sprays in improving crust-retention performance has yet to be demonstrated. Recent laboratory tests revealed that the addition of extra water to a coal surface previously sprayed with a latex-water emulsion did indeed provide deeper penetration, but it also increased run-off and inhibited or delayed the curing of the crust. However, even though the formation of a hard, stable crust was delayed, the increased depth of penetration of sealant fluids provided a moist layer under the crust which appeared successful in limiting particle shifting, a major factor in undermining crusts on sloped surfaces (Ref. 8).

Recent field observations (Ref. 10) of the effect on crust-retention performance of water-only sprays applied after a latex emulsion were inconclusive. The net effect appeared to be either negligible or detrimental. Additional research is required to determine whether flood water sprays, applied either before or after an application of chemical sealant, can improve crust performance.

Oscillating spray bars to increase surface coverage and preferential spraying, the application of more spray to trouble areas, were tried and abandoned (Ref. 3). However, because of the continuing problems with end-slope crust-retention, the authors of the recent field study recommended that the effectiveness of preferential spraying be rexamined, especially as a method of improving coverage on end slopes (Ref. 10).

Wind gusts during application have been observed to distort spray patterns and to redirect sprays away from coal surfaces which can result in incomplete surface coverage. Where this phenomenon is a problem, increasing spray pressure or reducing the height of the spray headers above the cars may reduce wind distortion; however, wind breaks or enclosures are recommended (Ref. 8).

Cold weather has caused freeze-up problems with spray system piping and nozzles. Unsprayed cars and on occasion completely unsprayed trains have resulted from spray system freeze-up. Unsprayed cars are unacceptable from an environmental viewpoint and coal mining companies should remedy this situation by upgrading their freeze-up protection system. Exposed lines and nozzles should be protected and lines purged after use.

4.1.3 Curing Time. The curing time for surface coatings is the time required for a sprayed solution to set or to reach a stable or best condition for sealing a coal surface. The laboratory evaluation of sealant crusts (Ref. 8) revealed that fully cured crusts are stronger and less prone to fracture by vibration than partially cured crusts.

However, the time required for a crust to fully cure may not be available. A unit coal train is normally loaded in 3 1/2 to 4 hours, therefore, prior to the start of a journey, the crust or surface coating on each car will have been curing for different length of time. The cars at the front of the train will have crusts that have cured for approximately 4 hours while cars at the rear will have crusts that have cured for only a few minutes. Fields observations have shown that the initial jolt or high amplitude shock at the start up of a 100 car train is sufficient to fracture the partially cured crust on a car at the rear of a train (Ref. 23). However, the results of the recent field study (Ref. 10) failed to confirm that there was any significant increase in crust-retention between crusts on cars at the front of a train and those crusts on rear cars. A more extensive evaluation of the possibility of improved crust-retention with fully cured crusts is required.

Regardless, for economic reasons, it is impractical to increase unit train round times, i.e. to allow loaded, sprayed trains to sit extra hours while crusts cure. Other methods suggested for decreasing the curing time of sprayed chemicals include: the application of heat to the surface of each car, the use of heated spray solutions, and the spraying of fast-curing chemicals (Ref. 8).

4.1.4 Vibrations, Shock, and Load Settling. Vibration and shock, factors inherent in the operation of a unit coal train, work against the successful performance of crusting or agglomerating chemicals. While a train is in motion the coal load, and hence any sealant coating, will be subjected to almost continuous low-level vibration and irregular high amplitude shock. Vibrations, which result primarily from wheel-rail interaction, vary in amplitude and frequency depending upon train speed and terrain. Shocks, which occur during starting, stopping, shunting and during high speed turns are usually of greater magnitude than the vibrations but occur less frequently.

During recent laboratory tests, it was shown that well-cured crusts could resist low-level vibration (less than 0.25 g) for over 20 hours without crust failure; however, a crust that had withstood ten hours of testing at low-level vibration with no damage could be destroyed in minutes by a slight increase in the amplitude of the vibration (Ref. 8).

It would appear that even a well-cured crust may not be able to withstand the violent shocks of a rough train journey, and once a crust has been broken low-level vibrations will contribute to crust undermining and the further destruction of the surface coating. Constant low-level vibration will shift coal from under a crust thereby undermining a partially covered surface (particularly on partially covered end-slopes)

causing further crust break-up and collapse (Ref. 8). A flat, completely coated surface will be least prone to shock breakage and vibration undermining.

Low-level vibration can also sift fine particles upward through cracks or gaps in a surface coating where they may become wind entrained. Depending upon particle size, vibration also appears to lower the threshold dusting velocity for particle entrainment. This phenomenon was demonstrated during laboratory wind tunnel experiments (Ref. 11).

Constant vibration will also result in the physical settling of a coal load. During an 1100 km trip to Vancouver the center portion of most coal car loads in one unit train were observed to drop, or settle, up to 30 cm (Refs. 10 and 23).

If a load settles uniformly, a well-cured crust appears to remain intact on flat surfaces but to break-up on distorted profiles or steep end slopes. The effect of load settling on crust break-up also appears to be severe at the edges of cars along the coal-steel interface. A well applied crust or surface coating which is in contact with the coal car side or sill will break away from the car side as the load settles.

At the end terminal, uncovered or exposed strips along the sides of most cars have been observed and photographed (Refs. 10, 18 and 23). These strips usually extend the entire length of the car along the central flat profile and vary in width from a few centimeters to almost 30 cm. These uncovered side strips may not result entirely from load settling, but rather from a combination of settling, improper spray application, and load-leveller profile aberrations created near the car sides.

At the end terminal the coal load along these strips has also been observed to be up to 20 cm below the coal load in the central, crust covered, portion of the car. The side troughs may also result from a combination of effects including: load settling, trenching by load-levelling equipment, and wind erosion of exposed coal.

It is unlikely that load settling can be reduced, however, the effect on crust break-up can be reduced if profile distortions are minimized and if sprays are applied to the total load surface.

4.2 Suggested Improvements to Spray Systems

4.2.1 Equipment Maintenance and Adjustment. Observation of loading and spraying operations at several of the western Canada coal mines (Ref. 10) has indicated that their spray systems frequently fail to cover the entire coal surface in loaded cars with sealant chemicals. Although some performance failures may be traced to poor spray equipment

design, spray coverage problems frequently result from temporary spray system faults introduced because of poor maintenance procedures.

Clogged or partially blocked nozzles, that redirect or distort spray patterns, cause partial surface coverage. Only one of the four spray facilities observed during a field evaluation achieved a high level of nozzle and spray pattern success on all of the trains checked (Ref. 10). Nozzle blockages, and improperly aimed nozzles were the reasons for incomplete surface coverage and wasted chemicals. A strictly enforced maintenance schedule for spray facilities is essential (Refs. 8 and 10). Spray nozzle and header operation should be assessed during each train spraying and malfunctions corrected before the next train is sprayed. Spray patterns should also be tested and verified before a train is loaded and sprayed.

Accurate timing of spray activation and shutoff is also essential for complete spray coverage. The timing of sprays is usually set to economize on spray solution that would be wasted on the ground between cars and to prevent the fouling of coal car operating equipment. However, mistiming can occur because of fouled automatic equipment or because of operator error in judging the end-of-car distance. Timing errors can result in partially coated end-slopes.

Coal mining companies should implement and adhere to a thorough maintenance schedule for their chemical spray and load-levelling apparatus. They should ensure that their systems are capable of total spray coverage of all end-slope areas and other exposed coal surfaces.

4.2.2 Back-up Spray Systems. Observation of the operation of spray systems indicates that the use of a single set of spray applicators (consisting of one or more spray headers) may not be sufficient to ensure adequate chemical sealant coverage on all of the coal cars loaded at a mine. In recent years, when asked to explain why certain trains were dusting "heavily", system malfunction was usually cited by coal mining companies as the reason for a particular train not being properly sprayed.

Nozzle plugging, spray bar freeze-up, automatic spray activation problems or operator error can result in a number of cars in a unit train receiving only a partial coating of sealant. In some instances, loaded cars will receive no spray at all. Exposed, unsprayed coal surfaces are known to be prone to the wind entrainment of fine coal dust en route and are therefore sources of nuisance dust pollution. These partially sprayed or unsprayed cars in loaded coal trains are unacceptable. Therefore, since time constraints do not allow for long delays while spray systems are repaired or while cars are backed up

for respraying, the installation of a second spray unit at each mine site would appear to provide the means of solving these problems without introducing costly delays.

Cars missed or only partially sprayed by the primary unit, the first set of headers, would be treated with sealant chemicals by the spray headers of the secondary or back-up spray unit. In the event of total failure of the first unit, the secondary spray unit would act as a complete standby system.

To operate the system, an observer or operator would be required to check each sprayed car, to pinpoint the cars requiring a respray, and to activate the secondary unit. All cars identified by the operator as unacceptable would be resprayed using the back-up spray unit. The secondary spray unit could also provide a means of preferentially spraying or double coating distorted profiles and steep end-slopes.

The following requirements are essential for proper operation of a secondary or back-up spray unit:

- the primary and secondary units should be sufficiently removed from each other to allow an operator to spot poorly covered cars and activate the back-up spray;
- the secondary unit must be independent of the primary unit, i.e. separate pumps, valves, meters, hoses, headers and nozzles;
- the secondary spray unit must have access to sufficient spray solution to coat an entire unit train with sealant spray at the required concentration (in the event of a complete malfunction of the primary unit);
- the secondary spray unit must be subject to the same strict design requirements and maintenance scheduling as the primary spray unit.

4.3 Load-Levelling Systems

The surface profile (the loading profile) of the coal in loaded cars is considered to be one of the most important factors in achieving good crust-retention with sealant chemicals. A flat profile will present the best geometry for sealant crust-retention and will create less unwanted air turbulence. Observations in the field and in the laboratory (Refs. 2, 8, and 10) confirm that most chemicals perform better when applied to level surfaces, therefore a flat surface on a coal load is an essential requirement for a high degree of crust-retention. A flat surface will also limit sealant run-off and crust undermining.

Cognizant of this requirement many of the coal mines in western Canada have attempted to improve the performance of their sprays by installing profile-levelling devices. However, there is no standard design, the levelling systems and the amount of

levelling achieved differ from mine to mine. Certain companies rely strictly on a wide flood-loading chute to level a load (Figure 2), while others have installed separate levelling devices. The load-leveller designs which have been tried or which are in use include: hard rubber flaps or skirts on loading chutes; hard rubber flaps on loading shed outlet doors; levelling bars; plow-type levellers; and levelling rollers. Most of the devices are attached to or immediately follow the loading chute, however, at some mines levelling devices are positioned further around the rail loop, separate from the load-out.

One of the inherent characteristics of unit train operation which makes it difficult to flat load a coal car is the requirement for a minimum loading time and hence the apparently inviolable feature that the trains must move while being loaded. Loading a moving car from a stationary chute in less than two minutes frequently produces either distorted profiles and long, steep, end-slopes (Figure 6).

Experience to date indicates that a completely level coal surface in a loaded car may be close to impossible to achieve given the current constraints of unit train operations. However, observation of the load-levelling facilities at certain mines has shown that some of these systems perform more effectively than others. Of the trains from the four mines observed during the system evaluation study, the two mines which loaded their trains with the flattest loading profiles also achieved the highest overall crust-retention averages (Ref. 10).

However, in order to achieve flatter profiles it is simply not a matter of installing levelling devices similar to those employed by the two companies mentioned above. The degree of success achieved with a levelling device depends not only upon leveller design but upon the type of coal car loaded, the characteristics of the coal on the day loaded, and the skill of the loading operator. The timing of coal release and shut-off is also crucial because it will determine the length as well as the angle of the end slopes.

One design of load-leveller was observed to produce almost ideal profiles. These profiles had short, small-angle front slopes, long flat central profiles and short, small-angle rear slopes with little or no coal left on the car sills. However, the attainment of these almost flat profiles was accompanied by near perfect timing of the release of coal into the front of the cars plus the accurate shut-off of coal near the end of each car. Load-out operator skill was instrumental in the success achieved. (Ref. 10).

Also, on the day in question, the train loaded comprised cars of almost uniform height containing coal loads at levels close to the top of the car sides. Coal car height can be a crucial factor with respect to achieving flat profiles, see Section 4.4.

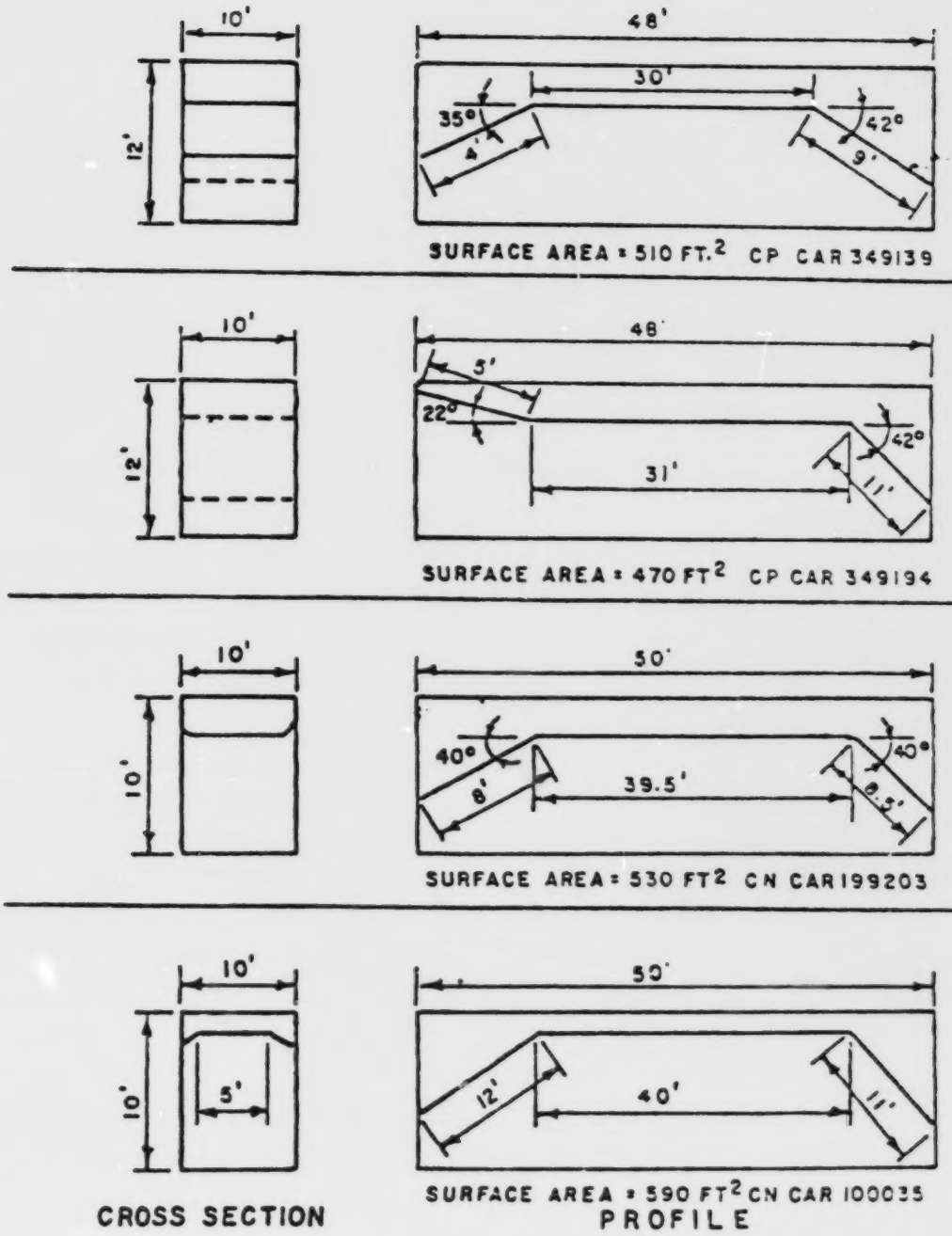


FIGURE 6 TYPICAL COAL-CAR LOAD PROFILES

Coal left on car sills has often been cited as a minor source of wind-blown dust. This problem is easily corrected by incorporating effective sill-sweeping devices as a necessary part of all load-levellers. Sill-sweeping devices should be employed at all coal load-outs in order to remove this known source of wind-blown dust.

Evidence collected since the original spray tests continues to confirm the theory that flat coal-load profiles are required for high crust-retention efficiency and adequate dust abatement. There is no optimum load-leveller design, operators should examine the most effective devices now in service and install load-levellers at their mines which are capable of obtaining the flattest load profiles possible on all of the various types of cars loaded at their mines. Side ridges, humped profiles, and steep end slopes should be significantly reduced or eliminated.

4.4 Coal Car Height

The two most successful load-levelling systems observed during a recent field study (Ref. 10) were employed at mines loading coal cars of near uniform height. The height of a coal car and hence the height of the car sill above the rails will affect the positioning (or repositioning) of loading chutes and levelling devices.

Car height differences, especially if they occur from car to car within the same train set, require a loading operator (or an automated loading system) to adjust the position of the loading chute (and the leveller height) for each successive car. The delays and errors accompanying these adjustments frequently increase the length and angle of the end slopes of the coal load and have been observed to lead to humped or distorted profiles. Load-leveller design is simplified if the unit train to be loaded comprises cars of approximately equal sill height.

The maximum weight capacity allowed by the railway companies for loaded coal cars is 119 275 kg (263 000 lbs, car plus coal load), therefore, the height of the coal load in a car will vary with the height and tare weight of each car. The height of the coal load in relation to the sill height of the car, either above, even with, or below, will influence load-leveller design and operation.

Many of the gondola-style coal cars now in service will exceed the maximum weight limit before they reach their bulk load limit. The result is that the top of the coal load is well below the top sills of the car (Figure 6). To level this type of load, a load-levelling device must clear the front of the moving car and drop down to reach the coal load. The time lost in such manoeuvres will increase the length and angle of the end slopes. Delays in lowering and raising loading chutes can also result in distorted profiles.

An effective load-levelling system should be capable of providing a flat load profile in each car regardless of coal load height.

Most of the unit trains loaded by the mines in northwest Alberta comprise cars of almost uniform height above the rails (coincidently the coal load height is almost even with the top sills). Observations (Refs. 10 and 18) show that these trains have consistently flatter load profiles than the trains loaded at the mines in southeast British Columbia. However, unlike the Alberta trains, most of the trains loaded in southern British Columbia comprise cars with sill heights which can vary up to 0.6 m from car to car within the same train set (Ref. 23).

It is likely that cars of unequal height and capacity will continue in unit coal train service, therefore load-levelling devices should be designed to overcome this inherent disadvantage. However, the railway companies could aid the mining companies by assigning cars of similar heights to specific train sets or by grouping cars of similar height and design within the same train set. A recent suggestion to install false bottoms in high-sided cars so they may be loaded to the top of the car sides requires investigation.

4.5 Operator Training and Automatic Systems

Some load-levelling and spray systems at the mine load-outs are manually operated. Observation of manual operations has shown that profile distortions and spray coverage irregularities can result from operators misjudging car heights and slope lengths in oncoming cars. In some cases an operator's job is complicated by load profile errors introduced by the loading personnel (Refs. 8, and 23).

A change of load-out personnel during train loading (a shift change) has also been observed to result in a number of cars with load-profile distortions occuring before new operators had become familiar with the loading rate of the falling coal. (Ref. 23).

The experience and skill of the personnel operating manually controlled loaders and levellers can be a determining factor with respect to the frequency of severe load profile distortions occuring in a given unit train.

Malfunctioning automated load-out equipment can also result in loading or spray system performance problems.

Training programs should be provided for load-out operators in the proper operating procedures for chemical spray systems and load-levelling devices. Operators and maintenance personnel should be well informed as to the importance of correct equipment operation to successful crust-retention performance and high dust control efficiency.

4.6 Overload Reduction - "Gouging"

The two major railway companies involved in moving coal by unit train in western Canada have both practiced en route, load reduction, "gouging", of overweight cars. They verify load weight by scaling cars en route, overweight cars are flagged, and the excess weight is removed by gouging the extra coal out of the centre top profile using a front-end loader or similar device. (In some cases, an entire train set is returned to the mine for load correction.)

Unfortunately when the railway companies remove a coal overload en route they also remove the sealant crust protecting that section of the coal load. Cars allowed to proceed in this state can be sources of wind-blown dust and therefore, from an environmental control perspective, this practice is unacceptable. Railway companies must investigate and implement alternative, environmentally acceptable methods of handling over-weight cars.

The coal mining companies also adjust overloaded cars. Normally "gouged" areas are subsequently sprayed, but, as with all sloped surfaces, crust performance in and around these gouges is poorer than on flat surfaces (Ref. 10).

Coal mining companies should either stop the practice of "gouging" their coal loads or they should make alternative arrangements to relevel these disturbed coal surfaces before they spray their trains.

4.7 Unloading Systems - The "Empty" Car Dusting Problems

"Empty" rail cars returning from Vancouver coal terminals to the coal mines have caused nuisance dusting en route. Although fewer dusting incidents have been recorded for empty trains than for full trains, some empty trains each year are judged to be "heavily" dusting, Table 1. Dust emissions from empty trains can result from coal which has remained on exterior car surfaces or inside of a coal car after dumping.

One coal terminal in Vancouver and the Ridley Island Terminal, Prince Rupert attempt to remove coal from exterior surfaces using an exterior car wash. Exterior car washing is the suggested minimum requirement for "empty" coal car dust control for all terminal operations. These car wash systems must incorporate wash water collection systems and the treatment of any effluent discharges.

However, although an exterior car wash can remove loose coal from the outside of a car it can not remove the coal left in car bottoms after dumping. All of the coal terminals in western Canada plus the Thunder Bay Ontario terminal employ rotary

dumpers to unload their unit trains. However, even though cars are inverted when dumped, some coal remains in the bottom. In winter this problem is accentuated by coal freezing to the sides and bottoms of the cars, increasing the quantity of coal not dumped. The amount of coal, water and ice remaining in dumped cars varies from less than a tonne during the summer to reported highs of 25 tonnes during the winter (Ref. 8). The railway companies report average frozen coal carry-back of 2.8 to 6.3 tonnes (Ref. 17). Frozen water and coal carried as dead-weight represents an economic penalty because it reduces the coal load carried and if thawing occurs en route it may act as a source of wind-blown dust.

Several of the coal mining companies in British Columbia were involved in a study during 1982/83 at the Roberts Bank Terminal in Vancouver to assess the effectiveness of chemical side-release agents. The work involved cleaning the interior walls of a number of test cars and applying a side-release chemical to the inside of the cars. The results of the study were inconclusive due in part to an unusual spell of warm weather in southern British Columbia, but regardless of the success of these agents, the cost of the treatment, reportedly approximately $30 per car, was felt to be too high for general application to all coal cars unloaded during winter months.

Thaw sheds appear to be effective in achieving more complete car dumping during winter months; both the Thunder Bay and Ridley Island coal terminals employ rail car thaw sheds. However, in southern B.C. thaw sheds have not been installed at the Vancouver terminals reportedly because thaw sheds are not cost effective in the prevailing moderate coastal climate. Although the coal freezes en-route, the industry has tolerated the economic penalties of carrying frozen coal.

A third method suggested as a means of removing coal retained on the inside of coal cars after they have been dumped is to wash the interior of the cars while they are inverted in the dumper. The disadvantages of this technique include extra moisture added to the coal during unloading, winter freeze-up problems plus the cost of retrofitting the dumpers with high pressure wash nozzles. The use of air jets rather than water jets could eliminate some of these disadvantages. A feasibility study is required.

Another solution to the empty-car dusting problems is automated car covers. A cover system would eliminate wind-blown dust emissions from coal carried on the inside of empty cars plus it would eliminate the dead-weight economic penalty of carrying rain, and snow in full and empty cars. Cover systems are discussed in detail in Section 5.2.6.

5 DUST CONTROL OPTIONS AND MITIGATION MEASURES

Several options have been suggested as methods for augmenting the dust control effectiveness of sealant spray systems, while others have been forwarded as replacement dust control techniques. In addition to technology options several mitigation measures have been suggested as means of reducing or dealing with the environmental impact of coal dust pollution from unit coal trains. A number of these dust control options and mitigation measures are listed in Table 11 (Refs. 3 and 29). In the discussion which follows the various mitigation measures and control options are grouped according to the coal industrial sector that would most likely be directly responsible for their implementation, i.e., the railway companies, the coal mining companies or the coal terminal operators. The advantages and disadvantages of each technology option are listed in Appendix A.

5.1 Mitigation Measures and Options - Railway Companies

5.1.1 Reduce Train Speed. Since 1981 a speed restriction, to 50km/h, has been implemented for dusting trains through one community in B.C. Whenever a train approaching the town is assessed as "heavily" dusting by the train crew, the train reduces speed. (At present this speed restriction is only temporary and not a legal requirement.) During conditions of little or no ambient wind, a significant decrease in visible dusting is observed if unit coal train speeds are held below 50 km/h (30 mph). However, although this operational procedure has been observed to be effective in reducing visible dust emissions, there are serious drawbacks to its general implementation.

Enforcement is difficult. When a train crew cannot easily determine if their load is dusting "heavily" (e.g., during non-daylight hours), the train will usually maintain its rated track speed (80 km/hr).

Another problem with speed reduction as a method of dust control is that during periods of dry weather and high ambient wind nuisance dusting can still occur even from slowly moving trains. Observations at Agassiz, B.C. have confirmed this phenomenon (Ref. 4).

However, economic penalties represent a more serious problem. Although dust emissions are less at lower train speeds, the Canadian Transport Commission and the railway companies are reluctant to impose or agree to mandatory speed reductions. A mandatory speed reduction in one town would not jeopardize existing train schedules; however a general requirement to reduce speed in all communities en route would result

TABLE 11 COAL DUST MITIGATION MEASURES

	Technique		Status
A)	**Options - Railway Companies**		
1.	Reduce Train Speed	-	In Use, One Community
2.	Uniform Design or Grouped Coal Cars	-	Too Many Mismatched Cars for either a Replacement or a Retrofit Program - Car Grouping Suggested
3.	Ban Above Car Loading	-	Not in Use
4.	Aerodynamic Modifications to Cars	-	Suggested - Design Required
5.	Switch to an Alternative Transportation Mode	-	Usually Impractical
6.	Cease Operations	-	Usually Unacceptable
7.	Reroute Trains	-	Not attempted - Impractical
8.	Buy Property or Homes	-	Considered to be Impractical
9.	Damage Compensation Payments-Yearly Stipend	-	Considered to be Impractical
B)	**Dust Control Technology Options - Coal Mining Companies**		
1.	Flat Load-Profile	-	Levelling Systems are In Use but Better Techniques Required
2.	Improved Chemical Sealant Application Techniques	-	Additional Experiments Required, Back-up Spray Required
3.	New Chemical Sealants	-	Chemical Sprays are Used by All Major Coal Shippers - New Chemicals Under Test
4.	Increase Chemical Sealant Concentrations	-	Have been Tested-Inconclusive Results
5.	Chemical Sprays - En Route	-	Suggested for Test
6.	Hinged Covers	-	In Use in U.S.A. - Redesign Required for Western Canada
7.	Liff-off Covers	-	Design Available - Prototype Testing Required
8.	Roll-Back Covers	-	Suggested - Design Required
9.	Soft Once-Only Covers	-	Suggested - Design Required
10.	Briquettes	-	Suggested
11.	Water Spray En Route	-	Not in Use

TABLE 11 COAL DUST MITIGATION MEASURES (CONT'D)

Technique		Status
12. Coarse Coal Topping	-	Attempted and Abandoned
13. Water Spray at Mine Load-out	-	Short Distance Only - Used on Some Coal Trucks
14. Remove Coal Fines	-	Not in Use - Impractical
C) Control Options - Coal Terminal Operators		
1. Interior/Exterior Car Cleaning	-	Exterior Car Washes at Two Terminals - No Interior Car Cleaning
2. Thaw Sheds or Side Release Agents	-	Thaw Sheds are In Use at Two Terminals; Side Release Chemicals are Under Test

in increases in round trip times and would seriously effect the movement of coal. There are over 30 small towns along the rail route from the coal fields in the southeast of British Columbia to Vancouver, a requirement to reduce speed in all of these communities would result in a need for more trains and more train crews to maintain the same annual volume of coal shipped. This is unacceptable since it would increase the cost of export coal and place an additional burden on the existing rail network. The rail system is already severely taxed to handle the present coal traffic.

Therefore, reduced train speed as a dust control option is only effective if used in conjunction with another abatement technique, such as sealant sprays, and is only economically viable as a dust mitigation measure for very specific locations and circumstances. For example, even after implementing the improvements recommended in this report, sealant spray systems may still malfunction and permit "heavily" dusting trains. Therefore, the railway companies must consider implementing a speed reduction for these few trains in order to reduce adverse nuisance dust impacts on communities along the rail corridors.

5.1.2 Uniform Design or Grouped Coal Cars. A sizeable fleet of cars with significantly different dimensions is currently in unit coal train service. The result of a non-standardized coal car fleet is that a mixture of cars of different sill heights can occur within the same train set. Car height differences within the same train set can

lead to non-flat coal profiles which can result in crust-retention problems and reduced performance effectiveness for spray dust-control systems.

A uniform design for all coal cars would solve some of these loading problems, but because of the large number of mismatched cars in unit coal train service, a car replacement or car retrofit program would be expensive and impractical. However, one suggestion for improving the existing situation is to organize train sets so that cars of a similar kind would be grouped together either as whole train sets or as groups of cars within the same train set. Implementation of this practice would introduce some scheduling problems and would require the cooperation and active participation of the railway companies, but it would facilitate loading and should produce more consistent, flatter load profiles in the loaded cars.

5.1.3 Ban Above Car Loading. Low bulk-capacity cars are frequently loaded with coal to a level above the sills in order to achieve the maximum allowable weight limit. Coal cars loaded in this manner expose the above-car coal surface to excessive wind erosion which leads to rapid crust-cover degradation. To avoid over-height car loading, it should be feasible to restrict load heights so that the top of the coal load is level with the top of the car sills.

However, a height restriction would reduce coal loads and the resultant economic penalty would result in increased transportation costs. A feasibility study to determine the economic penalties associated with this technique is required.

One suggestion for resolving the volume-limit load problem is to extend the wall height of a small bulk-capacity cars by adding side and end extensions; these extensions would bring each car up to its rated weight capacity. The difficulties involved in applying this technique are: extensions could interfere with loading and unloading apparatus, and the cost of retrofitting the cars could preclude this technique as a practical dust mitigation measure.

5.1.4 Aerodynamic Modifications to Cars. Experts in low speed aerodynamics have suggested that several longitudinal or lateral crossmembers fixed to the top of a coal car would reduce air turbulence and wind-over speed thereby reducing dust entrainment of surface coal particles. The feasibility and effectiveness of this technique is not known, studies would be required to develop optimum design configurations and to determine whether the reduction in fugitive dusting resulting from the installation of these devices would warrant the logistic difficulties and the expense of retrofitting the large fleet of coal cars.

5.1.5 Switch to an Alternative Transportation Mode. Switching from trains to another mode of transport is unlikely because in the majority of cases the coal mine location and the large volumes of coal to be moved leave no viable economic alternative to rail transport.

Coal slurry pipelines have been suggested as an alternative method of large volume coal transport; however there are many legal, economic and technical difficulties still associated with the transport of large quantities of coal over long distances by pipeline. A discussion of these difficulties is beyond the scope of this report but coal slurry pipelines are not considered to be a viable alternative to long distance rail transport in western Canada, at least for the near future.

5.1.6 Cease Operations. Closing down a coal/rail network would be a drastic form of control and would only appear to be a viable option if the cost of coal dust control should exceed the remaining revenue from a coal field.

5.1.7 Reroute Trains. The possibility of rerouting coal trains around communities has been suggested as a method for reducing citizen exposure to wind-blown coal dust. Although technically feasible such action would not prevent coal product loss and in most cases rerouting would prove to be too expensive.

5.1.8 Buy Property or Homes. The suggestion to purchase homes or properties that suffer nuisance dust impact from heavily dusting trains would seem unrealistic because of the large number of homes that fall within the range of the nuisance dust pollution. The legal ramifications of this approach are beyond the scope of this report.

5.1.9 Damage Compensation Payments - Yearly Stipend. The social, political and legal ramifications of paying citizens subjected to nuisance dust pollution a yearly stipend to compensate for property damage are also beyond the scope of this report. However, in general, because of damage assessment problems and administrative complexities this idea is felt to be an unrealistic approach to the dusting problem.

5.2 Dust Control Technology Options-Coal Mining Companies

5.2.1 Flat Load-Profile. Coal cars should be loaded with the surface coal profile as flat as possible. Evidence gathered during field studies and from laboratory tests continues to support the theory that chemical sprays will only be capable of adequate dust control if they are applied to virtually flat load profiles. Applying sealants to non-flat coal profiles appears to be one of the prime reasons for en route crust failure, but

although this requirement has been known for many years, no load-out facility in Canada is capable of achieving a completely flat load profile in a moving coal car. A discussion of the problems involved in coal car loading is contained in Section 4.3.

5.2.2 Improved Chemical Sealant Application Techniques. The application sequence for chemical spraying may influence crust retention. One sequence, employed at several coal mine load-outs, involves the application of chemical solution from one spray header followed by the application of a water soak from a second spray header. The purpose of the water soak is to increase crust penetration (Ref. 8), however, the results of field trials have been inconclusive (Ref. 10).

Another technique involves a sequence where one spray header coats the entire coal surface with sealant chemical while a second spray header applies a second coat of sealant only to steep end slopes. This technique, known as preferrential spraying, was used and abandoned by at least one company, but has recently received renewed interest because of the continuing problem of poor crust-retention on end slopes.

Another difficulty with existing spray systems is that they do not allow an operator to make corrections for poorly sprayed cars or for cars which do not receive any sealant chemical coating because of a system malfunction. Coal cars which do not receive an adequate coating of sealant chemicals can become sources of fugitive dusting en route. A secondary, or back-up spray facility at each coal load-out has been suggested as a technique for ensuring the complete chemical sealant coating of all coal surfaces.

Many spray sequences and application techniques are possible, research is required to optimize both spray system design and application methods.

5.2.3 New Chemical Sealants. It has been suggested that new sealant products or new chemical formulations could improve the crust-retention performance of the existing sealant spray systems. Since the inception of coal car spraying, numerous chemical formulations from a variety of suppliers have been marketed as coal dust suppressants or for other applications such as road dust control, see Appendix B (Ref. 30).

The most obvious advantage of a new and "better" chemical sealant is that the facilities for spraying the chemicals are in place at all of the major coal mine load-outs in western Canada and therefore the cost of implementation is low. The coal mining companies continue to experiment with new chemicals.

5.2.4 Increased Chemical Sealant Concentration. Increasing the concentration of commercial chemical sealant in the total fluid sprayed on each car could improve crust-retention.

Laboratory experiments (Ref. 8) have shown that in general higher concentration sprays provide stronger crusts, however in the field, the observed overall performance improvements have been minor (Ref. 10). Since the interaction of many performance related parameters can mask the effect of increasing sealant concentration, additional testing of chemical sealants at various concentrations is required in order to establish optimum concentrations for given operating conditions.

5.2.5 Chemical Sprays-En Route. The installation of one or more secondary chemical sealant spray facilities en route has been suggested as a means of controlling dust emissions through sensitive areas and communities. The en route spray systems would be installed at specific locations along the transportation corridor where the initial crust-cover provided by sealants sprayed at the mine load-out has broken down and satisfactory coal dust control is no longer being achieved. This technique is potentially feasible, but the associated capital and operating costs could be substantial.

5.2.6 Permanent Covers. The solution to the wind-blown dust problem suggested most frequently is to cover the coal cars. Although the concept of a covered car is relatively simple, the practical application of this dust control technique to the existing coal/rail network is technically complex. In 1981 Environment Canada commissioned an evaluation of the feasibility and cost of using coal car covers on unit trains in Western Canada. (Ref. 9).

The findings of the feasibility study (Ref. 9) indicate that a permanent, automated car-cover system would not only provide complete control of airborne coal dust emissions, but an effective cover system would also provide added economic benefits, such as alleviating the build-up of snow and rain in empty returning cars. However, there are, at present, major retrofit problems related to automated cover use in Western Canada which will delay their acceptance by the railways and the coal mining industry.

The coal industry is also concerned about cover and cover handling-system reliability in continuous unit train service. As noted in Section 3.1, the unit train concept is predicated upon rapid loading, unloading and transport of coal from mine to coal terminal, the industry feels that the inevitable delays caused by jammed or otherwise inoperative covers or cover handling-systems could result in serious economic penalties. The authors of the feasibility study (Ref. 9) felt the only way to overcome all of the compatibility difficulties was to employ a lift-off or removable cover. However, a complex design such as the lift-off system presented in Reference 9 is of particular concern to the coal industry especially during winter months when ice and snow would

cause serious operational problems with the cover batching and handling apparatus. The coal industry and federal transport officials have also stressed that a fail-safe cover clamp down system must be proven before automated cover systems would be acceptable.

There is one automated cover system in operation in the U.S.A. on unit coal train service (Ref. 32). Although difficulties were experienced during the early years of operation of this system, as "bugs" were worked-out-of unproven equipment, company personnel claim the system has been virtually breakdown and maintenance-free for the last five years. Based on recent observation of this system, automated covers may be classed as proven technology, at least for limited applications.

However, the system in the U.S.A., which employs a steel, hinged-cover, is designed for a specific coal mine to power plant operation. The western Canada coal transportation network is complex and before automated cover systems can become a reality in Canada a major integrated program involving government and industry to design and build an acceptable prototype system will be required. An engineering development of this kind could provide a new technology lead for manufacturers in the safe and economic transport of bulk materials by unit train.

Several different styles of permanent automated coal car covers have been suggested. Three types, removable, hinged and roll-back covers, are discussed below. The advantages and disadvantages of each type are listed in Appendix A.

Materials suggested for all three styles of permanent covers include: canvas, woven plastic, fibreglass, fibreglass-reinforced-plastic, rigid plastic, aluminum, steel, rubber and combinations of these materials. Because of the significant economic penalty associated with coal payload displacement due to cover weight, the materials used in the construction of the covers will be critical. Covers must not only be as light as practicable, but the cover material must be rugged enough to withstand extremes of ambient conditions, plus the very rough handling they will receive in unit train service. For these reasons "soft" cover materials such as canvas and woven plastic are felt to be impractial for continuous long-term use on unit coal trains. The merits of various cover materials are discussed in detail in Reference 9.

5.2.6.1 Hinged Covers. Hinged-cover designs include two piece covers hinged at the sides of the car which operate like a clam shell (Figure 8) or multi-segment covers individually attached with hinges to one side of the car box (Figure 9). The existing hinged-lid system in the U.S.A. employs a five section cover hinged to one side of the car (Ref. 32).

The main advantages of hinged-lid cover-systems in contrast to removable lid systems are:

- complex cover handling systems are not required. The lid-lifting or opening mechanism at the mine load-out is a simple scroll which requires little maintenance. Covers are designed to open by their own weight when inverted in a rotary dumper, there are no additional equipment requirements at the unloading terminals;
- although redesign is required for the Canadian scenario, hinged cover technology exists and has been proven in the field;
- hinged-lid systems are mechanically simpler with attendant better reliability.

The main drawbacks to hinged covers concern compatibility with existing facilities:

- the car clamp mechanisms on the rotary dumpers in western Canada are different from the one employed on the system in the U.S.A. Cars are clamped on the upper sill in the Canadian rotary dumpers whereas the dumper in the U.S.A. clamps each car on the lower sill thereby allowing full lid freedom during dumping.
- The existing hinged-lid system would require a major redesign before it could operate in conjunction with the smaller end-rings of the rotary dumpers used in Canada;
- the rotary dumpers at the west coast terminals do not all rotate in the same direction. These rotational differences combined with the railway's requirement for periodic car reversing to equalize wheel wear would necessitate complicated train switching arrangements in order to ensure that cars entered dumpers with the lids oriented in the correct direction. The rerouting and switching required could introduce delays and economic penalties;
- all of the load-out facilities in western Canada are different, many of the existing load-outs would have to be rebuilt to accommodate lid-swing, to allow scroll access and to restore loading operator visibility; and
- differences in rolling stock would require several different sized covers in order to fit all of the coal cars now in service.

Compatibility problems will make it difficult to develop a universal hinged cover design for retrofit into the existing coal/rail network.

5.2.6.2 Lift-off Covers. This style of automated cover system employs a single rigid-lid that is lifted off the coal car to allow unrestricted loading and unloading.

Construction materials can be selected to optimize service requirements of ruggedness, reliability, minimum weight and safety. The conceptual design for a removable lift-off fibreglass cover system capable of retrofitting to the existing unit train service in Canada is illustrated in Figure 7 (Ref. 9).

The principal advantages of removable covers in comparison to hinged covers include:

- the coal cars (with the covers removed) may still be used in service to shippers who are not equipped with a cover handling system at their load-out facilities;
- a removable lid system can be retrofit to the existing unit train service without major changes to coal mine load-out systems and car dumpers (although some minor modifications to these facilities would be required).

The main disadvantages relative to hinged-lid systems include:

- the technology for automated removable-lids is not proven whereas hinged-lid system technology is in operation in the field;
- a complex cover handling system with its attendant reliability and maintenance problems is required at both the loading and unloading facilities in contrast to the relatively simple fittings which would be required for a hinged cover system.

Other lift-off designs which belong in this category are non-rigid linked-rubber mats (similar to blasting mats) and solid flexible rubber mats. These mat style covers would fit inside the top of loaded cars, would be held down by their own weight, and would be removed by hooks snagging attached eyelets. Practical designs have not been developed.

5.2.6.3 Roll-Back Covers. This style of lid is designed to roll back into either an end or a side housing during loading and unloading operations (Figure 10).

The advantage of this system would be that cover opening and closing apparatus required at both the loading and unloading facilities should be relatively simple and should also be compatible with existing facilities.

The disadvantages relate to the lack of proven technology and the requirement for a potentially complex lid system with serious reliability problems due to jamming especially during winter icing.

5.2.7 Soft Once-Only Covers. The Saran-wrap approach or once-only cover system differs from the lid systems described above in that although the covering system is automated the coal cars are not fitted with a permanent lid. Instead, after coal loading,

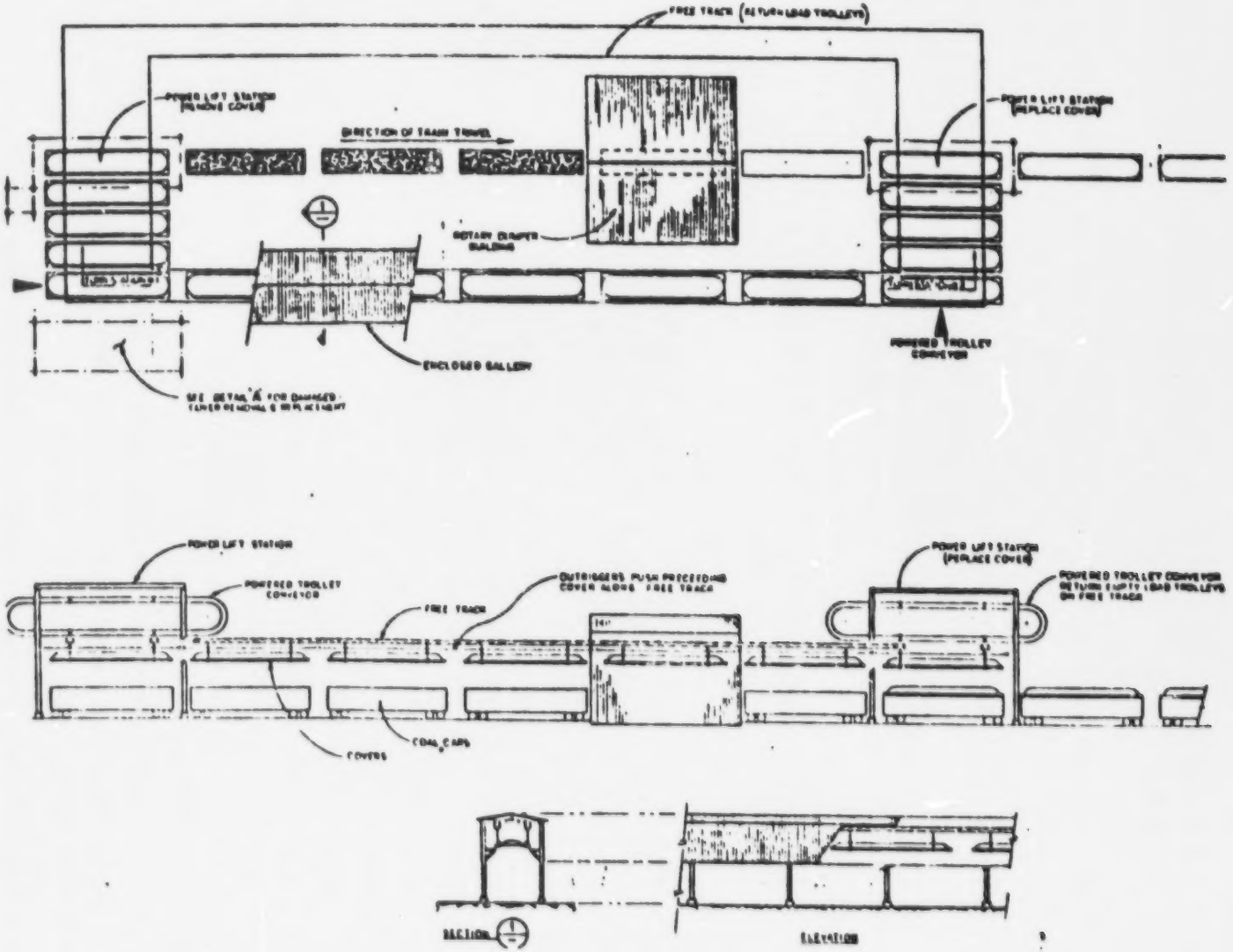


FIGURE 7 LIFT OFF COVER-HANDLING SYSTEM

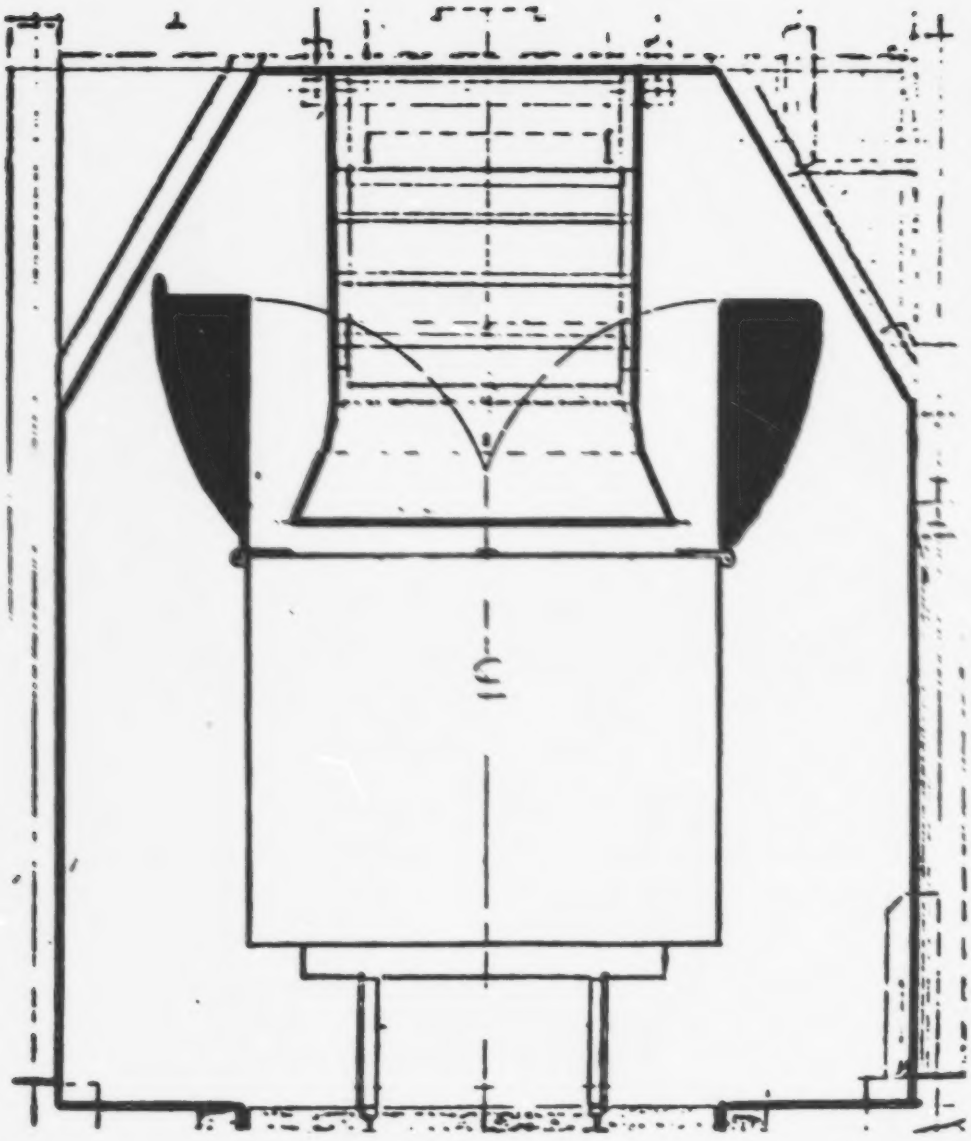


FIGURE 8 CLAM-SHELL HINGED-COVER

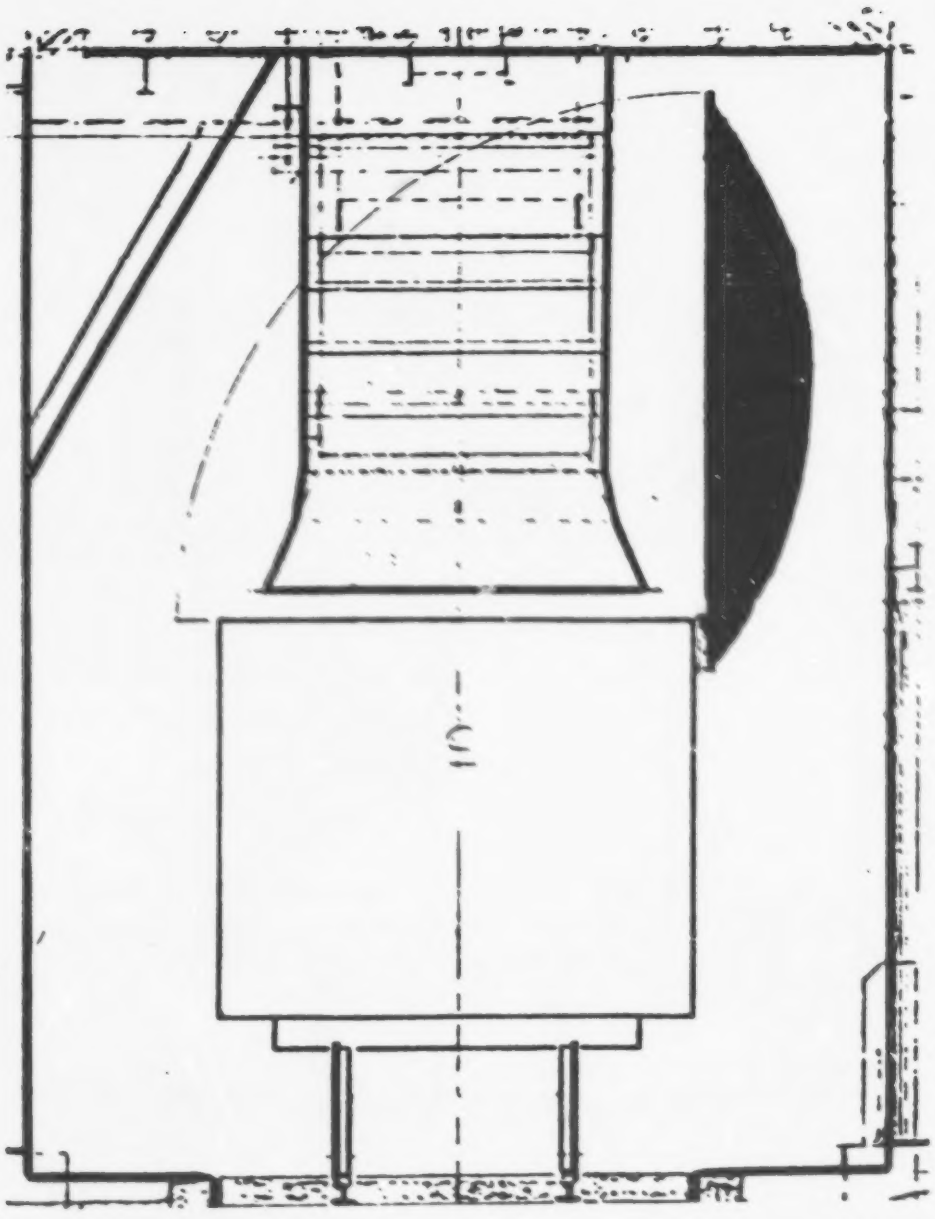


FIGURE 9 SINGLE-SIDE HINGED-COVER

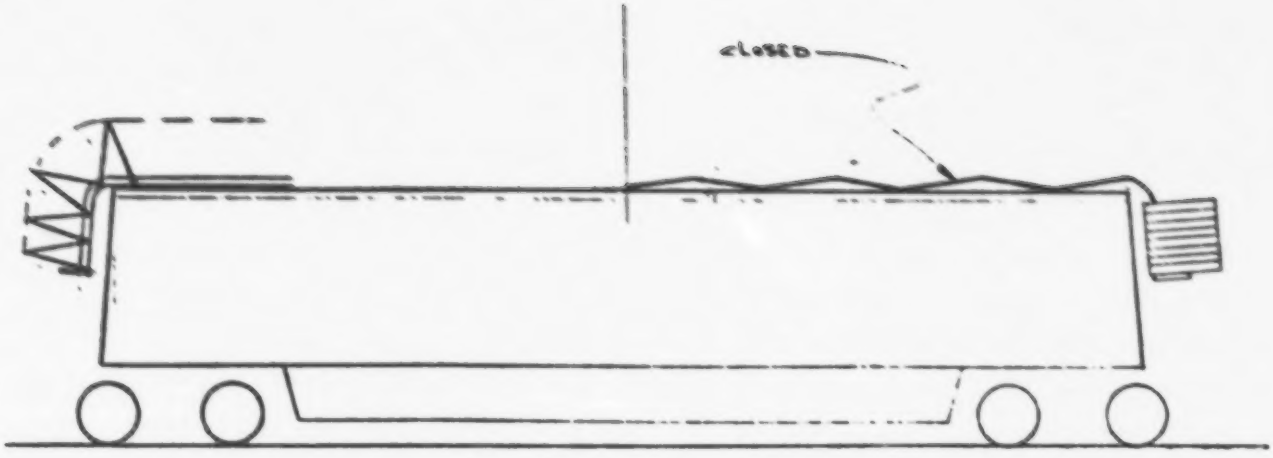


FIGURE 10 ROLL-BACK COVER

cars are fitted with a soft cover that is discarded at the end terminal. These covers differ from existing soft covers used in the ore transportation industry in that they would be applied automatically in order to conform to the time constraints of unit coal train operations.

Soft once-only cover systems would have several significant advantages when compared to permanent or fixed cover systems. These benefits include: the use of cars by shippers who do not have cover application equipment at their coal load-outs, lower additional weight per car, and less safety hazard in the event that covers are accidentally released in transit.

However, the once-only cover concept suffers because of a lack of proven technology for automation and the potential for frequent cover damage, and hence uncovered coal surfaces. Unless there is a breakthrough in the state-of-the-art for cover material, it is unlikely that a soft cover system will be practical.

5.2.8 Briquettes. Preparing coal for shipment in the form of briquettes, such as the familiar charcoal briquettes, would serve to agglomerate the coal fines and retain them within the coal cars. This is a novel approach with respect to large capacity coal production and has not been researched from this perspective. Although briquettes could reduce fugitive dust generation during all stages of product coal handling, the capital cost of the briquetting facilities could be prohibitive when applied to large scale coal production. Compatibility with end product use, especially in the metallurgical coal industry, would also require investigation.

5.2.9 Water Spray-En Route. Water sprays along rail trarsport routes have been proposed to augment the existing sealant spray systems. The water sprays would be installed at locations where the surface coatings provided by chemical sealants applied at the mines have broken down and are not achieving adequate coal dust control. The flood-water spray-systems would be located in advance of the communities where heavily dusting loaded coal trains have caused problems.

An en route, flood-water spray facility would be simpler than a chemical spray system because the spray bars could be built high enough above the track to allow free movement of all trains and no mixing apparatus would be required.

However, during dry weather a water spray would only solve the dusting problems of a single community and if spray systems were required before several communities en route, the installation and operating costs could be prohibitive.

Water sprays have been suggested for installation at end terminals to spray the inside of returning cars before shipment to reduce dusting from "empty" cars. However, adding large quantities of water to empty cars would cause car drainage and winter freeze-up problems.

5.2.10 Coarse Coal Topping. One coal mining company attempted to limit fugitive dusting by adding a layer of coarse coal over the top of each coal load, however the company eventually dropped the practice in favour of chemical sprays (Ref. 3).

Both the feasibility and effectiveness of this approach are questionable. The main disadvantages are: load-out systems would have to be re-designed to handle, store and load coarse coal, there may be insufficient coarse coal in the product stream to adequately cover every car, and a highly friable coarse coal will continue to breakdown and release fines even after separation.

5.2.11 Water Spray at Mine Load-Out. Because the surface agglomeration provided by a water-only spray would only last for a few kilometers (in hot, dry weather) water sprays would not be installed at mine sites as the primary dust control system unless transport distances were very short. This technique was employed by one coal mine to control dusting from trucks that carry coal on public highways from the mine to the preparation plant.

Water sprays containing surface-active or wetting agents would increase the depth of fluid penetration, but the exposed surface would still be prone to rapid dry out.

5.2.12 Remove Coal Fines. The suggestion has been made that coal dust emissions could be reduced if coal fines were removed from the product coal stream at a mine and only the coarse coal fraction shipped by rail. The coal fines would be separated and used near the mine site.

Although the separation of the fine and coarse coal fractions is an inherent feature within most coal preparation plants, the coarse and fine coal streams are usually recombined; new facilities would be required to handle both the fine and coarse coal fractions. A requirement for two separate product streams would also complicate product handling. More important however, considering the large percentage of fines in western Canadian metallurgical coal, a market for the coal fines in the vicinity of the coal mine would have to be found before the technique would be economically viable.

5.3 Control Options - Coal Terminal Operators

5.3.1 Interior/Exterior Car Cleaning. Coal dust blown from unit trains can originate from coal deposited on sills and other exterior car surfaces during unloading operations.

At present, coal is removed from exterior car surfaces at two coal terminals using an exterior car wash. Properly maintained exterior car washes are a minimum requirement for all coal terminals in order to remove this known source of fugitive coal dust emission.

However, an exterior wash will not reduce fugitive dust emissions resulting from coal retained on the inside of unloaded cars. Coal inside cars is another source of so-called "empty" car dusting. Coal could be removed from the bottom of rail cars using an interior car wash, however, because drainage systems in gondola cars are poor and likely to clog, it is unlikely that an interior car wash could be employed with the coal cars in the upright position. One suggestion for solving the car drainage problems and for removing coal from the inside of coal cars is to design an interior car wash which would direct clean-out sprays at the inside of coal cars inverted in a rotary dumper, the exterior surfaces of the cars would be washed at the same time. An investigation is required into the feasibility of installing interior/exterior car wash sprays within existing rotary dumpers which could wash off all retained coal without adding excessive quantities of water to the dumped coal. These water buildup problems could be eliminated by employing high pressure air jets to remove the undumped coal.

5.3.2 Thaw Sheds or Side Release Agents. During winter months moisture in coal can cause coal to freeze to car bottoms and remain there even after dumping. This phenomenon, referred to as "frozen coal carry-back", can impose an economic penalty on coal shippers and if frozen coal in "empty" cars thaws en route it can also become a source of fine coal for wind-blown dust emissions.

Two methods for removing frozen coal from loaded cars are: to install and operate thaw sheds at the end terminals or to employ "side release" chemicals to prevent coal build-up. Thaw sheds work, but coal mining companies claim that they are only economically viable in the colder regions of western Canada. For the warmer areas adding "side release" agents to the coal may solve frozen coal carry-back problems, but their cost effectiveness has not been fully assessed and further research is necessary.

6 COSTS - COAL DUST MITIGATION METHODS

Capital and operating costs are major factors influencing the selection of unit coal train dust-control systems. The only dust control technology in use on unit trains in Canada is to spray the coal with sealant chemicals at the mine load-out. A coal transportation network in the U.S.A. employs an automated cover system to control dust emissions and even though no such system has been installed in Canada, attempts have been made to estimate the cost of using car covers in western Canada. (Refs. 9 and 15). The discussion below centres on these two dust-control methods. An indication of the relative cost of other control technology options is presented in Appendix A.

The implementation of dust control technology entails both capital and operating costs, however it results in a reduction of coal losses and increased sales revenues. The cost effectiveness of the dust control measures will depend on the relative magnitude of the increased revenues due to coal loss reduction, compared to the costs incurred in installing and operating the dust control systems. Although chemical sealant systems have been operated in Canada since 1975, no reliable estimates of coal loss reduction during transport exist because of problems inherrent in making such measurement. Therefore, there is some uncertainty regarding the cost effectiveness of such systems and studies designed to estimate the overall cost of such systems have assumed levels of coal loss reduction.

Similarly uncertainty surrounds the estimated costs of operating automated rigid-cover systems in Canada. Although automated car-covers are proven technology (as demonstrated by the Gascoyne coal mine to Big Stone power plant system which has been in operation in the USA since 1975), there are major difficulties associated with retrofitting similar automated covers to the western Canada coal transport network. Incompatibilities with respect to the mixed fleet of cars, the variety of load-out configurations and the style of rotary dumpers would increase the cost of developing, installing and maintaining a universal cover system.Certain assumptions have been made when performing engineering studies to estimate the cost of implementing cover systems. These assumptions are largely unsubstantiated and uncertainty surrounds the cost estimates obtained.

Two studies (Refs. 9 and 15) have attempted to estimate the cost, in Canada, of using chemical sprays and rigid cover systems for coal dust control. One of the studies (Ref. 15) was performed for a group of coal producers, in 1980, by a team of consulting firms investigating the potential for coal dust contamination of wood pulp at the then

proposed Ridley Island coal terminal and the other for Environment Canada (Ref. 9) as background material to establish a code of good practice. Both studies involved comparisons of the cost of dust control using chemical sprays, steel covers and fibreglass covers when shipping coal a distance of 1100 Km. Unfortunately the cost estimates in both of these studies contained assumptions with respect to many of the unsubstantiated parameters which biased the final overall cost estimates in favour of the preferred dust control system.

The following analysis uses the same cost estimating technique as employed in References 9 and 15 but adjusts the assumptions to remove the bias. A more detailed discussion of these two studies is presented in Appendix C.

6.1 Chemical Spray Systems and Rigid Car-Covers

An attempt has been made to improve upon the previous cost estimates (using the same costing technique employed in the Ridley Island Study, Ref. 15), by updating the historic costs to present value for similar equipment and eliminating obvious bias. Table 12 presents the anticipated costs of operating the conceptual spray and cover systems. Because of the uncertainty attached to many parameters and the number of assumptions required, high and low estimates have been provided for each control system. An indication is also given as to how much the unit transportation cost (assumed to be $19 per tonne) would be increased by implementation of the control measures. A description of how these costs were generated is presented in Appendix C.

Table 12 also indicates the relative contribution of the major cost components (materials, labour, maintenance, capital costs and displaced cargo charges) to the overall cost of operations. In general (except for the extra wheel-maintenance factor for steel-hinged covers), the impact of assumed labour and maintenance requirements on the overall costs is low.

The following points are noted for the specific systems:

(a) Chemical Spray Systems

The implementation of chemical spray systems results in two major costs, firstly the direct cost of the chemicals used and secondly an indirect freight penalty introduced as a result of the weight of the sprayed fluids displacing coal cargo.

The cost of control using sprays is very sensitive to the amount of chemical used, spray materials account for approximately 60% of the estimated system costs. In comparison the labour, maintenance and capital charges are minimal, Table 12.

TABLE 12 ANTICIPATED OPERATING COSTS OF THREE DUST ABATEMENT METHODS

Parameter	Chemical Sprays Low	Chemical Sprays High	Fibreglass Lift-Off Covers Low	Fibreglass Lift-Off Covers High	Steel Hinged-Covers Low	Steel Hinged-Covers High
Operating Cost $/Tonne Coal Shipped -*	0.16	0.34	0.57	1.18	0.88	1.31
Estimated % Increase in Shipping Costs -**	1% to	2%	3% to	6%	5% to	7%
Relative Influence of Cost Components (%)-						
Labour -	1	3	3	2	0	0
System Maintenance -	1	2	13	11	5	3
Extra Wheel-Maintenance -	0	0	0	0	0	15
Chemicals -	64	60	0	0	0	0
Capital Recovery -	4	8	58	67	41	28
Displaced Cargo -	30	27	26	20	54	54
	100	100	100	100	100	100

* The derivation of these estimates is described in Appendix C.

** Assumes a shipping cost of $19 per tonne.

Varying a number of the spray system cost parameters has produced cost estimates in a range from $0.16 to $0.34 per tonne of coal shipped. The corresponding estimated increase in the shipping costs was 1 to 2 percent (Table 12).

Coal product loss en route due to fugitive dusting is not a true spray system cost, however, since spray systems do not provide 100% dust control (while cover systems do), the importance of this factor with respect to other spray system cost parameters has been tested. The effect on the overall system cost of adding a coal dusting loss factor (decreasing the dust control from 100% to 85%) was to increase the "high" cost estimate by approximately 30%. (Appendix C).

(b) Steel Hinged-Covers

Rigid, steel covers represent a capital intensive means of dust control. A fully developed and tested system would involve minimal direct operating charges, other than for cover maintenance. The capital charges involved in amortizing the equipment over its estimated useful life were estimated as 28 to 41% of the total expenses.

A major expense involved with the steel cover system occurs indirectly as a result of the heavy covers which reduce the coal carrying capacity of the cars. It has been estimated that this cargo displacement factor can be responsible for approximately half of the overall costs.

A second, sizeable indirect expense is the increased car maintenance which may be introduced due to the inability of the railroad companies to exercise normal car rotation procedures designed to balance uneven wheel wear. Investigators (Ref. 15) felt that lids hinged to one side of a car would require the car to be hauled in the same direction at all times, the extra maintenance required could represent up to 15% of total system costs.

The steel hinged-cover operating cost estimates range from $0.88 to $1.31 per tonne of coal shipped and would increase the shipping costs by 5 to 7 percent (Table 12).

(c) Rigid, Fibreglass, Lift-off Covers

Installation of fibreglass covers would result in a similar expense profile to that of the steel covers with the major cost being the amortization of the capital cost of the covers, and their handling system, over their useful lives. Capital recovery is estimated as up to 67% of total system costs. The second largest cost would be the indirect cost of reduced coal carrying capacity due to cover weight. The influence of this factor is very sensitive to the assumed weight of the covers. Cover weight penalties could account for up to 26% of the total system cost.

For the conceptual designs studied the fibreglass covers were lighter than the steel-lids, hence the magnitude of the freight penalty was lower. Also, a car rotation penalty for this cover system was not included since the style of cover assumed in the conceptual design is a lift-on, lift-off lid and the cars could still be rotated to equalize wheel wear.

The conceptual system (Ref. 9) envisaged a labour requirement but this accounts for a minimal proportion of the overall costs. The anticipated cover maintenance costs were higher than those of the steel covers due to the less durable properties of fibreglass.

The operating cost estimates range from $0.57 to $1.18 per tonne of coal shipped and would increase the shipping costs by 3 to 6 percent (Table 12).

It must be emphasized that uncertainty surrounds many of the operating costs associated with the various coal dust mitigation measures. This is especially true for the rigid cover systems, since no system presently operates on a mixed fleet of cars as operated in Canada. Assumptions with respect to unsubstantiated costs account for the variation in the cost estimates produced by different investigators. An attempt has been made to indicate the influence of changes in the values of the different cost components on the overall costs, Table 12. The dominance of particular factors is indicated as a percentage of the total cost.

6.2 Benefits Derived from Dust Mitigation Measures

Reduction in the amount of coal lost from unit trains during transport provides a number of tangible and intangible benefits to the coal companies and society. However it is difficult to quantify many of these benefits since there are no accurate measurements available as to the percentage of coal lost from unsprayed and sprayed cars and there is no automated cover system operating in a scenario similar to the complex western Canada coal transport network. The benefits derived in previous reports (Refs. 9 and 15) were based on widely differing assumptions many of which are virtually unsubstantiated.

The major tangible benefit provided by dust control is the reduced loss of coal and therefore the greater tonnage of coal delivered to the ports. Through implementation of dust control measures the mining companies derive higher revenues in proportion to the increment in coal delivered. Canada also derives increased export earnings from the savings. This coal is valued at its sales revenue which at present is approximately $60 to $70 per tonne, depending upon market conditions.

If one accepts that between 0.5 and 1.8% of a coal load may be lost from untreated cars during a typical journey of 1100 km from a Western Canadian coal mine to the terminal, then potential revenue losses could amount to between $0.30 and $1.08 per tonne of coal transported at today's coal prices ($60 per tonne). Mitigation measures will then be cost effective if they can reduce the dust losses while keeping the cost of the dust control below the resulting product "loss savings". The value of the "loss savings" will depend upon the level of uncontrolled and controlled dust emissions, both of which (for chemical spray systems) remain unquantified.

In addition to the revenue savings, the following benefits are also provided by coal dust control:

(i) lower soiling damages as a result of decreased coal losses;

(ii) a reduced potential for industrial cross-pollution at sites en route. Concern has been expressed by certain pulp and paper producers that soiling of their finished pulp by coal dust could affect their product quality;

(iii) enhanced visibility. A dusting coal train detracts from the visual beauty of the scenery en route;

(iv) fewer citizen complaints re nuisance coal dusting incidents.

6.3 Other Control Options

Other options than chemical sprays and permanent covers have been suggested to solve the dusting problems. These systems have not been subjected to extensive cost analysis, however, Appendix A lists the suggested options and describes their advantages and disadvantages.

6.4 Conclusions re Costs and Benefits

Dust abatement measures provide the tangible benefit of increased coal sales revenues as well as other less tangible benefits, such as decreased soiling, lower industrial pollution and decreased citizen concern. Insufficient data exist to permit a meaningful evaluation of these less tangible benefits, however the savings resulting from the use of the existing spray systems could range from zero to approximately one dollar per tonne of coal-transported, depending on by how much chemical spraying reduces dust loss (as compared to the cost of spraying).

Currently spray systems are assessed as the least expensive means of dust control with the estimated operating costs ranging between $0.16 and $0.34 per tonne of coal transported. The cost of control using rigid cover systems is higher: the probable

cost for steel hinged-cover systems is estimated to range between $0.88 and $1.31 per tonne and fibreglass lift-off covers from $0.57 to $1.18 per tonne. The lack of an operational cover system similar to what would be required in Canada introduces a high degree of uncertainty with regard to the operating cost estimates for the rigid cover systems.

While cover systems are currently assessed to be more expensive to operate, a properly designed rigid cover will provide a more effective means of dust control. However, it is concluded that further engineering studies are required to develop conceptual design alternatives for car cover systems, in order to assess in more detail the associated capital and operating costs for cover systems. The variation in the cover system cost estimates, being in the range of $ 0.57 to $1.31 per tonne of coal carried, reflect the uncertainties and gaps in the knowledge base. The efficiency of the existing spray systems in reducing dust losses should also be studied to determine how cost effective these systems are and whether permanent covers could provide further coal loss reductions to offset the additional costs involved in their use.

7 RECOMMENDATIONS AND CONCLUSIONS

Since the early 1970's, coal producers have made major strides in reducing the impacts of fugitive coal dust from their loaded coal trains. The implementation, in 1975, of chemical sealant sprays in western Canada significantly reduced fugitive coal dust emissions, however, the overall performance of these systems has not reached the high levels of dust-control efficiency predicted during the early prototype tests. In addition, several of the coal shippers and coal terminal operators have as yet been unable to solve recurring problems related to the long term operation and reliability of their dust-control systems. "Heavily" dusting coal trains continue to occur and consequently nuisance soiling by dust emitted from unit coal trains is still a problem in several communities in southern British Columbia.

The principal recommendation of this report is that each coal producer and coal terminal operator in Western Canada shipping coal by unit train over long distances should install coal-dust control systems which will eliminate "heavily" dusting loaded and empty coal trains and minimize the adverse air quality impact of fugitive coal dust on communities along the related rail corridors.

In order to meet these objectives the overall performance of the existing dust control systems must be improved and major system breakdowns eliminated or reduced in frequency. The alternative is to switch to new, more effective, methods of dust control.

7.1 Coal Car Covers

The most effective method of containing coal cargo within railway cars, and thereby eliminating the related problems of coal product loss and nuisance coal dusting from both loaded and empty trains, is to provide a permanent cover over each car. For limited use, automated cover systems for unit trains are proven technology, however, there is no off-the-shelf system currently available for retrofitting to the complex western Canada coal-transportation network. Extensive reconstruction of existing facilities would be required to accommodate present cover designs.

However, considering the long-term advantages to be derived from this future technology, the coal mining industry should continue the investigations begun by Environment Canada into automated cover technology. A prototype design, construction and testing program is required in order to develop a cover system which could be used in western Canada.

Considering the existing technological problems, the uncertainties with respect to operating costs, and the resistance to car covers within the coal industry, it is

unlikely that any coal-car cover system will be operating in Canada within the near future.

7.2 Chemical Spray Systems

In reviewing all of the coal dust mitigation measures which have been suggested, it is evident that the existing dust control technology, using sprayed chemical sealants, is, at present, the control measure preferred by coal producers and is likely to remain so for at least the near future. Therefore, the minimum requirement for fugitive dust control is a chemical sealant spray system installed at each coal load-out. The chemical spray system must be capable of covering each coal car with an adequate quantity of chemical dust suppressant.

The measures listed below define certain design, maintenance and operating requirements for improving the existing spray dust-control systems. Recommended monitoring requirements and performance goals are also included.

7.2.1 Crust-Retention Goal

The percentage of crust-cover-remaining (or crust-retention) on cars arriving at the unloading terminal is the present method of estimating spray system performance and dust control efficiency (as measured by the observed ratio of crust-area-remaining to the total surface area of the load profile). A performance goal of 85% crust-retention, as agreed to by the coal mining companies in 1975, was considered the minimum requirement for nuisance dust control and achievable with conventional spray equipment. This goal does not appear to have been met, but with standardized training, operating and maintenance procedures, the 85% standard should be achievable on a consistent basis using the existing sealant spray equipment. Therefore, coal shippers should ensure that the crusts on the cars in all of their loaded trains arriving at the unloading terminals in western Canada meet the 85% minimum crust-retention goal.

However, crust-retention is not an absolute indicator of coal-dust emission control, therefore since the coal dust problem may persist in spite of achieving an 85% crust-retention, the coal companies should work toward the goal of dust elimination rather than crust-retention in order to prevent nuisance coal dust impacts.

At present, higher crust-retentions, in the range of 90% to 95%, are achieved on individual cars, however, it would appear that major changes to spray application techniques, spray equipment and load-levelling devices will be necessary before crust-retention averages of 95% or greater can be consistently achieved.

Coal mining companies must continue to implement methods of improving the consistency and overall performance of their dust control systems in order to eliminate "heavy" dusting trains and to reduce dust emissions. They must strive to achieve a level of dust control that will reduce the quantity of emitted coal dust to a level that is acceptable to communities and citizens affected by coal dust pollution from coal trains.

7.2.2 Performance Monitoring

Following the approach adopted by other industries with respect to corporate responsibilities towards environmental control, the coal mining companies shipping coal to terminals in western Canada should implement year-round monitoring programs to assess the effectiveness of their dust control measures.

These self-assessment programs should include both assessments of the crust-retention on coal cars arriving at end terminals and en route dust monitoring programs. Observers should be employed at each end terminal to check and record a statistically significant number of coal cars and unit trains in order to demonstrate that the 85% minimum, or higher level, crust-retention goal is being achieved.

Coal mining companies should cooperatively implement and operate air quality monitoring stations at selected sites along the rail transportation corridors where fugitive coal dust pollution is a concern. The assessment of visible dust emissions by track-side observers is the quickest method of reporting "heavy" dusting trains to the coal mine operators. Visible dust assessments should be used until satisfactory dust monitoring instrumentation is developed.

In view of the historical and continuing concerns over nuisance coal dust impacts for communities in the Fraser Valley of British Columbia, air quality monitoring along this route should be implemented as soon as possible.

The implementation of the monitoring programs and the reporting requirements should be developed in consultation with and be approved by relevant government agencies.

7.2.3 Chemical Spray and Load-Levelling Installations

In order to meet and maintain a high standard of system performance and dust control efficiency the following minimum requirements for the design and operation of chemical spray facilities are necessary. The measures listed below are based on the findings of laboratory tests, system monitoring studies and observations of the western Canada coal-transportation network by various investigators over the last decade.

A. Maintenance and Training

Observations have indicated that many spray application facilities are neither adequately inspected nor maintained. Each mine should implement, and adhere to, a thorough maintenance schedule for their spray systems which include pumps, mixing equipment, spray nozzles, spray headers and load-levelling devices. All spray headers and nozzles should be purged and tested, plus the spray patterns and the solution consistency verified before each train is loaded and sprayed. Load-levelling devices should be checked for correct operation before each train is loaded.

Observation has shown that operator error can result in reduced crust-retention performance. Training programs should be developed and load-out operators trained in the proper operating procedures for chemical spray systems and load-levelling devices. The importance of correct equipment operation for successful crust-retention performance and high dust control efficiency should be emphasized in these training programs.

B. Spray Facility Design

In order to standardize design and to improve performance consistency, all chemical spray systems should include the following design features:

- spray patterns should be protected from distortion by wind;
- freeze protection measures or equipment are required for all exposed piping, headers and nozzles to prevent the freezing of fluids during the worst winter conditions;
- nozzle patterns must be designed to coat all of the exposed coal surface on every car;
- sprays must turn on and off rapidly in order to effectively coat all critical coal surfaces near the front and rear of each car;
- the spray system should incorporate mixing and flow-metering equipment which will ensure the uniform application of evenly mixed sealant chemicals, of the desired concentration, over all coal surfaces irrespective of train speed through the load-out.

C. Load-Levelling

Most chemical sealants have demonstrated an inability to form coatings that will adhere to sloped or irregular surfaces, therefore each coal mining company equipped with a spray system should install an effective load-levelling device capable of obtaining the flattest possible profile on their loaded coal cars. Side ridges, humped profiles, and

steep end-slopes should be significantly reduced or eliminated. Load-levelling devices should be designed to adjust (or be adjusted) to the height of all sizes of coal cars being loaded.

D. Back-up Spray System

In spite of the incorporation of the design standards listed herein, spray system breakdown and other errors during the application of chemical sealants to loaded coal cars will still occur. Spray system failures, which result in unsprayed cars, can lead to "heavily" dusting trains en route. To combat this problem and to ensure that every car is coated with an adequate quantity of sealant, each mine-site spray system should be equipped with two separate spray units.

Each of the two spray units, a primary and a secondary, should employ separate pumping equipment, piping, spray headers and nozzles. The spray headers and nozzles of the secondary spray unit should be physically separated from the first spray unit and at sufficient distance to allow an operator to identify problem cars and to activate the second spray unit. An operator should inspect each car as it is sprayed; all cars identified by an operator as unacceptable (unsprayed and partially sprayed cars) should be sprayed by the secondary spray unit. Both spray units should conform to the design criteria listed herein and the secondary spray unit should have access to sufficient chemical sealant to spray an entire unit train. In the event of the total failure of the primary spray unit the secondary unit will therefore serve as a complete standby or back-up spray system.

E. Chemical Sealant Research

Operating experience and research indicate that improved crust-retention performance from chemical spray systems may result from operating the spray systems using optimum techniques (spray concentrations, solution volumes per car, application methods and crust curing times) for given ambient conditions. Chemcal sealant suppliers should establish the optimum conditions for using their dust suppressants and the coal mining companies should endeavour to employ these optimum procedures when spraying their unit coal trains. In addition, the mining companies and chemcal suppliers should continue the testing of new and improved sealant chemicals an other methods of improving chemical sealant crust-retention performance.

7.3 Sill Cleaning

Each coal mining company should incorporate a sill-sweping device into its load levelling system to remove loose coal from the top sills of all coa cars.

7.4 Car Cleaning Systems

Loose coal on exterior surfaces of "empty" cars can be a source of wind-blown coal dust. Each coal terminal should install and operate a car wash to clear sills and exterior car surfaces of loose coal prior to the cars commencing the return journey to the coal mines.

However, an exterior car wash will not remove coal from the inside of dumped "empty" cars. Coal remaining in the bottom of cars after dumping, referred to as carry-back, (either dry or frozen-coal carry-back) can become a source of fugitive dust and the weight of the carry-back represents an economic penalty to coal shippers.

The coal mining companies and the terminal operators should continue their investigations of side-release agents, thaw sheds and other methods for improving car dumping and eliminating coal carry-back. The feasibility of air or water jets designed to remove coal from the inside of cars while they are inverted inside rotary dumpers should be determined.

7.5 Reduced Train Speed

It is recognized that the operation of mechanical dust-control systems, regardless of the design and maintenance procedures employed, can not be perfect, and "heavily" dusting trains may still occur even after the coal producers and coal terminal operators implement the recommendations listed herein. Therefore, it is further recommended that the railway companies consider the implementation of a policy that requires all "heavily" dusting trains to reduce speed in communities where dusting will cause a nuisance pollution problem.

7.6 Overload Reduction - Gouging

The railway and mining companies should cease the practice of removing coal from overloaded cars by "gouging" the surface or they should implement procedures to level and respray all cars whose loads have been corrected.

7.7 Coal Car Height

The height of a coal car will influence the successful operation of loading chutes and any subsequent load-levelling devices, therefore, the railway companies should endeavour to group cars of the same height, either as complete train sets or as groups of similar cars within the same unit train. This practice will simplify the loading operator's task and should contribute to attaining flat coal profiles on a more consistent basis.

8 REFERENCES

1. "Minimizing In-Transit Windage Losses of Olga Low Volatile Coal", Denton, G.H., et al., Dowell ltd., 1972.

2. "In Transit Control of Coal Dust from Unit Trains", Fisheries and Environment Canada, Technology Development Report, Guarnaschelli, C., EPS-4-PR-77-1, May 1977.

3. "Control of Coal Dust Pollution During Railroad Transportation - A State-of-the-Art Review" Hardy Associates (19719) Ltd., for Kaiser Resources Ltd., August, 1979.

4. "A Report on the Monitoring of Particulate Emissions from Coal Trains at Agassiz, British Columbia", EPS, Pacific Region, Poon, Dr. D., Cope, D.L., Wituschek, E., Holmes, J., Kerby, D., Kerby, G., October 1984.

5. Memorandum: D.K. Sandberg to B. Manna, Province of British Columbia, SUBJECT: Project - Coal Train Monitoring, October 12, 1982.

6. "An Assessment of the Effects of Traffic Growth on the Railway System Serving Roberts Bank", Project No. 21147, Swan Wooster Engineering Company Ltd., for the Roberts Bank Expansion Railway Committee, October, 1981.

7. "Biological Testing of Canadian Coal Dust Samples for Genotoxic Activity", British Columbia Cancer Research Centre, for Environment Canada, March, 1982.

8. "The Testing of Coal Rail Cars Sealant Sprays and Loading Techniques Designed for the Abatement of Fugitive Coal Dust", Williams, C.J., Schuyler, G.D., Waechter, W.F., MHTR Ltd., for Environment Canada, May, 1982.

9. "Feasibility, Cost and Conceptual Design Study of Automated Coal Car Cover Systems for Abatement of Fugitive Coal Dust from Unit Trains", Cambrian Engineering Group Ltd., Calgary, May, 1982.

10. "Performance Evaluation of Chemical Sealants and Crust Retention on Loaded Coal Trains", IEC Beak Consultants Ltd. and C.G. Environmental Engineering Ltd., for Environmental Canada June, 1983.

11. "Testing of Emission Factors - Fugitive Coal Dust from Unit Trains - A Laboratory Evaluation", MHTR Ltd., June, 1983.

12. "Testing and Evaluation of Methods for Collection and Analysis of Coal Dust from Unit Trains," Environmental Sciences Ltd., for Environment Canada, Vancouver, August, 1984.

13. "Field Test of EX 11-7 at B.C. Coal", Diachem Industries Ltd., Service Report, 20 Jul., 1982.

14. "Spraying Coal Cars with Binder No. 1324, 3 September, 1980", Trip Report, Shank, J.L. Davis Gelatine Ltd., 9 Sep., 1980.

15. "A Study of Coal Dust Contamination of Canadian Cellulose's Watson Island (Prince Rupert) Pulp Mill for the Operation of a Coal Terminal on Ridley Island and Coal Unit Train Access and Egress to the Proposed Terminal", Beak Consultants, Hardy Associates (1978), Sandwell and Company, Swan Wooster Engineering Company, September, 1980.

16. "Measurement of Fugitive Dust from In-Transit Unit Trains Near Agassiz, B.C., C.G. Environmental Engineering Ltd. for Elk Valley Coal Producers, November, 1983.

17. "Flow-Related Problems in the Distribution of Western Canadian Coals", H.G. Engineering Ltd. and Lemberg Consultants Ltd., March, 1977.

18. "Report of a Field Study - Coal Train Sealant Spray Performance Evaluation", Holmes, J.D., Cope, D.L., Margitay, J., Wituschek, E., Environment Canada, January, 1982.

19. "DOE Coal Study - Draft", EPS, Ottawa, 18 December, 1980.

20. "Future Coal Prospects - World Coal Study", Ballinger Publishing Company, Cambridge, Massachusetts, 1980.

21. Canadian Coal Industry Data-Base and Air Emission Forecast Program, Transport Systems Division, Industrial Programs Branch, EPS, Environment Canada, October 1983.

22. "Wind Entrainment of Coal Particles and Its Control", Brown, R.A.S., and Speichert, A., Alberta Research Council.

23. "Trip Report - Fugitive Coal Dust Emissions from Coal in Railroad Cars. Observations from Western Canada", Environment Canada, Cope, D.L., July, 1980.

24. "In-Transit Wind Erosion Losses of Coal and Method of Control," Mining Engineering, Nimerick, K.H., and Laflin, G.P., August, 1979.

25. "A Study of Coal Dust Emissions from Ontario Hydro Unit Coal Trains", EPS, Environment Canada, Ontario Region, McCoy, D., January, 1980.

26. "Use of the Ames Test to Evaluate the Mutagenicity of Compounds in Runoffs from Model Coal Piles, Stahl, R.G., et al, University of Texas at Houston, School of Public Health, May, 1983.

27. Letter from Frame International Inc. to Environment Canada, 1 October, 1982.

28. "Supplementary Evaluation of Performance of Chemical Sealants on Loaded Coal Trains," C.G. Environmental Engineering Ltd for Environment Canada, 15 March, 1984.

29. "Techniques for the Control of Fugitive Dust from Unit Coal Trains", Cope, D.L., International Congress of Technology and Technology Exchange, Pittsburgh, May, 1982.

30. "Chemical Spray Sealants for the Control of Wind-Blown Coal Dust from Unit Trains-A Listing of Names and Specifications", IPB, EPS, Manuscript Series, Environment Canada, Cope, D., Wituschek, E., Poon, D., June, 1984.

31. "Report on the Application and Performance of the Sealant Solutions Sprayed on Coal Loaded Railway Cars on March 24th and 25th, 1980" Hardy Associates (1978) Ltd., for Environment Canada, April, 1980.

32. "The Flip Top Lid", Progressive Railroading, June, 1975.

APPENDIX A

ADVANTAGES AND DISADVANTAGES OF THE VARIOUS TECHNIQUES FOR CONTROLLING WIND-BLOWN COAL DUST FROM UNIT TRAINS

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ADVANTAGES AND DISADVANTAGES OF THE VARIOUS TECHNIQUES FOR CONTROLLING WIND-BLOWN COAL DUST FROM UNIT TRAINS

A.1 Introduction

The mitigation measures and control options for coal dust were discussed in section 5, the perceived or recognized advantages and disadvantages of the principal technology options are listed below.

A.2 Technology Options - Railway Companies

A.2.1 Uniform Car Design or Grouped Coal Cars

The reason for a uniform car design or the grouping of cars of the same size is to allow loading of cars of the same sill height and capacity.

Advantages:

- may reduce train loading times;
- will aid flat profiling in individual cars;
- car grouping would require no capital investment;
- a new car design could increase coal pay load;
- a new car design could improve coal dumping and reduce coal carry-back.

Disadvantages:

- a sizeable fleet of mismatched cars are in service, therefore the retrofit of extensions or reductions to cars in order to introduce uniformity within the fleet would be expensive and impractical. Introducing cars of a new design would add another car type to the present mixture;
- consensus on a "best" design could be difficult;
- new designs or car grouping are not control measures, but only act to supplement or improve the chemical spray dust control systems;
- the degree of dust control improvement achieved by an improved car design could be marginal and not warrant the expense;
- grouping cars will add scheduling problems and possible round trip delays.

Cost: A retrofit program to bring all cars in service up to the same design is unlikely because of the large number of cars that would

have to be rebuilt or removed from service. New cars introduced into service could be built to a universal design, particularly with respect to sill height, and it is unlikely that building cars to a universal design would add appreciably to new car construction costs. Grouping cars of the same design would add little to overall system costs.

A.2.2 Aerodynamic Modifications To Cars

Advantages:

- additions to cars could reduce the wind over the coal surface and thereby reduce fugitive dusting;
- no per car materials cost once installed;
- no additional operators required.

Disadvantages:

- unproven, research required to test the feasibility;
- extra car maintenance will be required;
- a mismatched fleet of cars complicates the retrofit;
- the structural additions must be strong enough to withstand the rigors of the loading/unloading procedures;
- the structural additions could hinder coal dumping. In particular the unloading of frozen coal could present a major problem if new structures span the top of a car.
- any structural additions must not interfere with loading/unloading equipment at the mine and at the terminal;
- the weight of the additions would add to car tare weight and would reduce the coal load;
- a chemical spray or other dust control system may still be required if dust control is not complete;
- coal cars must be removed from service during the retrofit.

Cost:

Depending upon the materials used and the design selected, the capital cost of the structural additions should be low, although installation and demurrage charges during the retrofit program would increase the total cost.

A.3 Dust Control Technology Options-Coal Mining Companies

A.3.1 Flat Load-Profile

Most evidence supports the theory that flatter coal profiles are required for adequate sealant crust-retention.

Advantages:

- improved crust-retention will improve dust control;
- no per car materials cost.

Disadvantages:

- a flat profile is difficult to achieve without stopping the train while loading;
- research into the "best" load-leveller design is required;
- since all coal load-outs are different, no optimum design may be possible;
- a flatter profile may not necessarily ensure adequate dust control unless accompanied by other system improvements;
- a new or redesigned load-out may be required to accommodate the leveller;
- the optimum load-leveller may require a full-time operator;
- extra maintenance required for an optimum load-leveller;
- a uniform car design may be required in order to achieve a flat load profile.

Cost: The capital costs would be high if the redesign of the coal load-out is required. A full-time operator may be required.

A.3.2 Sprays. Spray systems and modications to spray systems have the following features in common:

Advantages:

- systems for applying fluids to coal trains are in place at all of the major coal exporting mines in western Canada;
- trained operating and maintenance personnel are available at most mine sites;
- no modifications to rolling stock are required.

Disadvantages:

- close to 100% fugitive dust abatement may not be possible for any spray system;
- winter freeze-up of the spray equipment is a problem and protection must be provided;

- a back-up system is required to coat any unsprayed cars;
- a coal load-levelling system is required;
- spray installations require frequent maintenance in order to maintain dust control performance levels;
- sprays do not prevent the build-up of snow, ice and rain in the returning cars;
- spray fluid weight supplants coal weight;
- mine site spray facilities do not solve empty car dusting problems;
- high winds can hamper proper spray application;
- a spray operator is required to monitor system performance.

A.3.2.1 New Chemical Sealants

Advantages:

- chemical storage and handling systems are in place;
- crust-retention averages could be improved.

Disadvantages:

- new chemicals may not significantly improve crust-retention;
- performance would still be dependent upon operating efficiency and environmental factors;
- improved load-levelling devices and other system improvements may still be required;
- research into the effectiveness of new chemicals is required;
- new chemicals may damage rail cars;
- per car materials cost (chemical costs) are escalating.

Cost: For a 5% solution, 9 litres (2 gal) of commercial latex sealant per car, the materials cost was approximately $8 per car, new chemicals could escalate that cost.

A.3.3 Improved Chemical Sealant Application Techniques

Advantages:

- increased crust-retention and increased dust control could result;
- low cost depending on the system changes required;
- no additional materials cost;
- a back-up or secondary spray system would be a step toward eliminating "heavily" dusting trains.

Disadvantages:
- positive results are unproven since no optimum design is available;
- additional maintenance would likely be required if more complex spray apparatus or a second spray system were installed.

Cost: The addition of new, more complex equipment would increase operation and maintenance costs.

A.3.4 Increased Chemical Sealant Concentration

It has been suggested that increasing the concentration of the commercial sealant in the present spray solutions and emulsions would improve crust-retention.

Advantages:
- increased crust-retention would increase dust control;
- no additional personnel required;
- quick implementation;
- no additional maintenance required.

Disadvantages:
- increased per car materials cost;
- may not provide sufficient additional dust control to justify the increased cost per spray application;
- research into the effectiveness of high concentration sprays is required;
- higher concentration chemical sprays may increase the damage to rail cars.

Cost: The coal mining companies spend $8 to $12 per car to spray a unit train with commercial sealants which cost approximately $0.90 per litre ($4/gal). If the present quantity, 9 litres (2 gal) per car, were doubled or tripled, the cost of materials would increase to $20 or $30 per car.

A.3.5 Chemical Sprays - En Route

Advantages:
- a chemical spray applied en route after load settling may improve overall dust control;
- technology and trained operating personnel are available.

Disadvantages:
- there are no spray systems in place at en route sites;
- indiscriminate spraying could damage rail cars and engine

units, therefore spray headers must be designed to swing away from tracks. This swing-away requirement would complicate design and increase maintenance costs;

- maintenance would be required for each spray unit;
- full-time operation and maintenance personnel would be required;
- per car materials cost (chemical costs) are escalating;
- sprayed fluids add to total car weight;
- collective agreement would be required by all of the mining companies using the spray systems;
- could increase the overall round trip time if spraying must be performed at lower than normal train speeds;
- research is required to ascertain the best en route site locations.

Cost: Capital would be required to build the en route spray system or systems, but this cost would be shared by a number of coal mines. Maintenance costs would be higher than for the present mine site facilities because of increased usage. Full-time operating personnel would be required at en route sites unless a fully automated system were developed.

A.3.6 Permanent Covers. Automated cover systems employing a hard or permanent lid have the following features in common:

Advantages:

- covers represent an effective solution to the fugitive dusting problem and may be the only system capable of close to 100% dust control;
- supplemental dust control systems such as chemical sprays are not required;
- covers will eliminate the build-up of snow, ice and rain in returning cars;
- covers represent a solution to "empty" car dusting problems;
- permanent covers do not create a waste problem;
- once installed there is no per car materials cost.

Disadvantages:

- covers may not be able to withstand the rigors of the coal handling network without considerable maintenance;

- the weight of the covers will reduce the coal load in each car;
- the "mixed bag" of coal cars now in service will hamper the development of a universal cover and cover handling system;
- dry and frozen coal carry-back may still be a problem due to inherent moisture;
- there exists a possibility of spontaneous combustion;
- damaged or jammed covers will cause loading and dumping delays and increase round trip time;
- coal build-up on car sills may hamper lid sealing;
- winter icing may hamper cover opening and sealing;
- a fail-safe lid locking mechanism is mandatory and the possibility of cover loss may increase insurance costs;
- there will be a considerable lag time to design, build and install the systems;
- any latches and fittings must not interfere with loading or dumping mechanisms;

For additional detail on cover systems, see Reference 9.

Note: The requirement for a fail-safe locking or securing mechanism must be stressed. Without such devices covers of any design are unacceptable.

Cost: Refer to the cost discussions in section 6.

A.3.6.1 Hinged-Lids

Advantages:

- a functioning automated system has been in use in North America since 1975;
- no additional equipment is required at the end terminal;
- the cover handling apparatus at the mine load-out is of simple design and relatively easy to maintain.

Disadvantages:

- because of incompatibilities with present rotary-dumpers and load-out facilities, major modifications to existing facilities would be required;
- mismatched rolling stock will complicate the development of a universal cover design;
- not all dumpers rotate in the same direction therefore the

operation of cars with lids hinged to one side will cause difficulties;

- car rotation for uniform wheel wear will be complicated;
- a hinge-lid car may only be used by companies with a lid opening system.

Cost: In 1975 the prices for the components of the one functioning automated cover system using hinged lids were listed as: covers, $4500 (U.S.) per car ($0.5 million per train) and the unlatching system $78 000 (U.S.) for an installation where the loading system required no restructuring. A 1981 estimate of the lid costs was $8 000 per car.

A.3.6.2 Removable-Lids

Advantages:

- this style of cover would be compatible with the existing loaders and unloaders;
- no restriction of loading operator's view;
- covers can be removed so that cars may be used by shippers who do not have a cover removal system.

Disadvantages:

- unproven technology, no automated system is available;
- cover removal and replacement systems are required both at the mine and at the end terminal;
- because covers must be removed and replaced, the handling systems are more complex than for other cover systems;
- because of the handling system complexity, the maintenance requirements will be greater than for other cover systems;
- The lack of permanent hinges means that fail-safe hold-down devices are more important for this type of cover.

Cost: Complex cover removal systems are required at both the coal mine and at the end terminal, therefore the capital investment plus maintenance costs for this type of cover system will be greater than for hinged or roll-back cover systems.

A.3.6.3 Roll-Back Covers

The lid components of this style of cover would be designed to roll back into an end or side housing during the loading or unloading operations.

Advantages:

- cars with the lids stowed may still be used by companies with no lid opening system;
- the chance of lid loss is reduced with this style of cover;
- the unlatching mechanisms would be minimal therefore this type of cover would be compatible with most loading/unloading facilities;
- this style of cover would more easily adapt to a mismatched fleet of cars.

Disadvantages:

- no proven technology exists;
- the covers would be intricate, multi-sectional devices, thus cover maintenance would be high;
- the intricate covers would be readily susceptible to damage from rough use;
- cover hardware and the housing must not project beyond the present maximum dimensions of a car;
- there is a greater probability of cover jamming especially from ice and snow accumulation;
- the cover may require power to open.

Cost: Because of the intricate nature of the covers, the per car installation costs would be higher than the other cover types, but the ground installations should be the least expensive of all the cover systems.

A.3.7 Soft Once-Only Covers

Advantages:

- the displaced cargo weight due to cover weight would be lower than for any other cover system;
- coal cars may still be used by shippers with no cover handling system;
- less danger from en route cover loss.

Disadvantages:

- because the covers are disposable, there would be a materials cost per car;
- there is no technology available. A rugged cover material and an automatic tie-down system are required;
- disposable covers would be a source of waste;

- since covers are disposed of at the end terminal, this style of cover does not solve the "empty" car dusting and other returning car problems;
- damaged covers and hence dusting cars are more likely than with other lid systems;
- depending upon the cover hold-down system employed cover removal at the end terminals could cause delays.

Cost: Several large mineral mines employ 2 or 3 operators to hand cover their ore cars with woven plastic covers. The cost per car, exclusive of manpower cost, is approximately $25.

A.3.8 Briquettes. A method of reducing the amount of fine coal available for wind entrainment would be to briquette the coal, or otherwise compact the coal into pieces too large to be entrained by all but abnormally high winds.

Advantages:
- no additions to the railway rolling stock are required;
- the existing coal handling equipment should be able to cope with the briquettes. Little additional equipment would be required;
- there are no per car materials cost.

Disadvantages:
- a briquetting facility must be built at each mine;
- coals may not easily briquette;
- end users may require un-briquetting facilities to render coal to its original form;
- briquettes could break during handling and shipping and create fines which would dust;
- any substance added to the coal to produce the briquettes must not affect the properties of the coal as required by the end user.

Cost: The capital cost would be high to build briquetting facilities at every mine.

A.3.9 Water Spray - En Route

Advantages:
- simpler than a chemical spray system, therefore lower maintenance;
- should eliminate emissions at problem locations;

- the sprays do not damage rail cars;
- low per car materials cost;
- no speed reduction is necessary during spray operation.

Disadvantages:

- no systems now in place along the rail lines;
- operating personnel or automation would be required at each en route location;
- maintenance would be required for each unit;
- many systems would be required to protect all dust zones;
- fluids added en route would increase the total loaded weight of the cars;
- collective agreement would be required by all companies using the route;
- water availability may cause problems in certain locations.

Cost:

Water sprays have only a short range effectiveness, therefore there could be a requirement for over 30 spray units along the rail corridor in southern British Columbia if each community along the route requested a system for dust protection through their town. The estimated capital cost of a chemical spray facility is $125 000 to $250 000, water spray systems will cost less but the defrosting, pumping and the equipment for automation will influence the per unit cost. The capital investment required for a large number of spray stations may be unacceptably high.

A.3.10 Coarse Coal Topping

Advantages:

- no additions to cars would be required;
- no additional per car materials cost.

Disadvantages:

- the effectiveness of this technique will vary with the thickness of the coarse coal layer and the size of the coarse coal;
- there may not be sufficient coarse coal (lumps greater than 9 mm, 3/8 inch) in a product stream to provide a blanket of large coal over the load in each car;
- coarse coal silos and handling equipment may be required;
- highly friable coarse coal will continue to break into finer pieces even after separation;

- some fine coal could adhere to the larger pieces of coal and thus would be available for wind entrainment;
- this technique does not solve the dusting and snow buildup problems associated with "empty" cars.

Cost: Capital investment would depend on the coarse coal handling and storage equipment required at each mine.

A.3.11 Water Spray - Mine Load-Out

As a primary, mine site, dust abatement system:

Advantages:
- low per car materials cost;
- the sprays do not damage rail cars;
- flood spray bars can be built high enough to allow free passage of the engine units, therefore maintenance requirements are less than for chemical systems.

Disadvantages:
- in hot, dry weather water sprays are only effective for a few kilometres.

Cost: Capital, operating and maintenance costs would be lower than for chemical spray systems, however, because of their limited effectiveness, water sprays would not be installed as primary, mine site, dust control systems unless transport distances were very short.

A.3.12 Remove Coal Fines

Advantages:
- no per car materials cost;
- if the existing coal preparation plant separates fine coal, no major modifications would be required.

Disadvantages:
- even after separation the highly friable, coarse coal would break apart to create additional fines during handling and en route;
- because of the quantity of fines in western Canada coal they cannot be discarded, a market for fines must be created in the vicinity of the coal mine. If no market is found, the technique is economically unacceptable;
- separate handling facilities for coarse and fine coal would be required.

Cost: It is unlikely that a market for a large quantity of coal fines will be found in the area of most coal mines therefore the lost product revenue that would result from this practice would be unacceptably high.

A.4 Control Options - Coal Terminal Operators

A.4.1 Combined Interior/Exterior Car Cleaning

Exterior car washing alone does not solve the problem of dusting from coal left inside dumped cars. The total cleanout of "empty" cars will require a combined interior/exterior car cleaning facility.

Advantages:
- will solve both the "empty" car dusting and the coal carry-back problems;
- air jets, as opposed to water sprays, would not add water to coal;
- no per car materials cost.

Disadvantages:
- water from sprays directed into upright cars may collect in the bottoms of the empty cars;
- a redesign of the rotary dumpers to accommodate the water or air jets would be required;
- there would be an interruption of the coal/rail network during installation;
- water sprays could result in winter freeze-up problems in the dumpers;
- car cleaning does not alleviate loaded car dusting problems;
- could increase coal moisture content;
- interior car cleaning would not solve the problem of rain and snow build-up in returning cars.

Cost: The initial cost could be high if major modifications to each rotary dumper were required.

A.4.2 Thaw Sheds or Side Release Agents

Advantages:
- if complete car dumping is achieved then these techniques could solve the "empty" car dusting and coal carry-back problems;

- additional equipment requirements for side release agents are minor.

Disadvantages:

- the capital cost for a thaw shed is high;
- the effectiveness of side release agents is still under evaluation;
- do not alleviate loaded car dusting problems;
- the application cost per car for side release agents is high.

Cost:

The preliminary estimate for side release chemicals is $30 per car, therefore the cost of coating every car in every unit train arriving on the west coast with a side release chemical would be prohibitive. The investment and operating costs for a thaw shed are high.

APPENDIX B

CHEMICAL SEALANTS AND BINDING AGENTS FOR COAL DUST SUPPRESSION

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CHEMICAL SEALANTS AND BINDING AGENTS FOR COAL DUST SUPPRESSION

B.1. Introduction

There are many chemicals on the market which are marketed as, have been tested as or are being used as dust suppressants, Table B.1 (Ref. 30). No attempt has been made to rank these products.

WARNING: The mention of product names in this report does not represent an endorsement by Environment Canada.

TABLE B.1 CHEMICAL SEALANTS AND BINDING AGENTS FOR COAL DUST SUPPRESSION (unranked listing)

No.	Brand Name	Main Base Constituent	Manufacturer or Distributor
1.	Coherex	Asphalt	Witco Chemical Canada Ltd.
2.	GCP Dust Suppressant 200	?	Betz Laboratories Inc.
3.	Coal Cover	Coal/Wax/Plastic	Atlantic Research Corp.
4.	Darex 3333	Latex	W.R. Grace & Co.
5.	EX 11-7	Sulphite Liquor	Diachem Industries Ltd.
6.	Bond-All NJ	Petroleum Resins	Norjohn Contracting Ltd.
7.	Calcium Chloride	Calcium Chloride	Allied Chemicals Ltd.
8.	IPG-60	Gelatine	Davis Gelatine (Canada) Ltd.
9.	M-167.2	Latex	Dowell of Canada
10.	M-166	Latex	Dowell of Canada
11.	Vultex 2-V-5522-B	Latex	General Latex and Chemicals
12.	ICA-16 TRET-O-LITE	Acrylic Copolymer	Petrolite Corp. of Canada
13.	Coal Pile Retainer	Resins	West Chemical Products of Canada Ltd.
14.	Nalco 8820	Latex	Alchem Inc.
15.	AMS 2000	Acrylic Polymer	Arco Chemical Company
16.	Pentron DC-8	Acrylic Polymer	Apollo Technologies
17.	Gamresin WP24	Resin	Gamlen Chemical Co.
18.	Colas Crusting Agent	Asphalt	Flintkote
19.	Micro-Foam	Surfactant	Deter Company Inc.
20.	Compound SP	Latex	Johnson March
21.	Starch Spray	Starch	Industrial Grain Products
22.	M-218	Polymer in Oil	Dowell of Canada
23.	AMS 2010	Asphalt	Arco Chemical Company
24.	Hercobind DS-3	Emulsified Resin	Hercules Inc.
25.	Bindtex	Polymer	Rogers Bros. Ltd.
26.	Dust Ban 8A08	Polyacrylamide	Alchem Inc.
27.	Van Kap 1000 (AMS 2200)	Petroleum Emulsion	Van Waters and Rogers Ltd.
28.	MWR 078 & 082	?	Mine Waste Reclamation Ltd.
29.	Hynate S-1	Surfactant	Mitsui Co.

TABLE B.1 CHEMICAL SEALANTS AND BINDING AGENTS FOR COAL DUST SUPPRESSION (Unranked listing) (Cont'd)

No.	Brand Name	Main Base Constituent	Manufacturer or Distributor
30.	Reclamation Oil	Oil	Cominco
31.	Dust Suppressant 100	Asphalt	Pounder Emulsions Ltd.
32.	Dust Suppressant 200	Asphalt	Pounder Emulsions Ltd.
33.	Dowell M167	Latex	Dowell of Canada
34.	Alchem 63026	Latex	Alchem Ltd.
35.	Acquatain	?	Whitlock Construction
36.	Lignin Derivatives	Pulp Mill Waste	Cominco
37.	Coal Spray 100	Oil	Imperial Oil
38.	Triton CF-10	?	Rohm & Haas Company 1976
39.	Lignosulfonic Acid	Lignosulfonic Acid	
40.	Flintkote SS-1	Asphalt	Flint Kote
41.	Heavy Residual Oil	Oil	
42.	Alchem-Nalco 5WM-493	Latex	Alchem Ltd.
43.	Bitumen	Bitumen	Cominco
44.	Water & Surfactants	Water & Surfactants	
45.	Curasol AC	Copolymeric Plastic	Mackenzie & Feimann Ltd.
46.	Dowell M145	Latex	Dowell of Canada
47.	Cyanaspray	Latex	Cyanamid of Canada Ltd.
48.	Geo Cote 8-4	?	Trans Can Grouters Ltd.
49.	Van Kap 300	?	Van Waters and Rogers Ltd.
50.	DLR-H,S	Acrylic	Rohm & Haas Ltd.
51.	Hot Melt	Slack Wax	
52.	Daratak SP-1065	Polyvinyl Acetate	W.R. Grace & Co.
53.	Everflex GT	Copolymer	W.R. Grace & Co.
54.	Esco M105	?	ESCO
55.	Wax 778	Slack Wax	Imperial Oil
56.	Wax Emulsion	Slack Wax	Imperial Oil
57.	Oil QE2296A	Oil	Imperial Oil
58.	Oil QE2298A	Oil	Imperial Oil
59.	Wax-Oil-Water	Wax	Airth Group

NB Detailed specifications, where available, are presented in Reference 30.

APPENDIX C

COST ESTIMATES - DETAILS

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C.1 PREVIOUS COST ESTIMATES - DETAILS

The reports of two investigations into fugitive dusting from coal trains, References 9 and 15, contain cost comparisons of chemical spray systems and permanent, automated, cover systems. These two reports represent the basis for developing the control system cost estimates discussed in Section 6. The underlying assumptions used for each of these two sets of calculations are discussed below.

C.1.1 Ridley Island Study - Cost Comparison

A preliminary cost analysis study carried out in 1980 in relation to potential coal dust problems at the new Ridley Island, B.C. coal terminal compared fibreglass covers and steel hinged-lids to chemical sealant sprays. (Ref. 15). The assumptions used to arrive at these estimates were as follows:

- Movement of five million tonnes of coal 1 125 km from two coal mines located in Northeastern British Columbia to Prince Rupert.
- Movement was made in 100 car unit trains, each car having a capacity of 91 tonnes.
- Transportation cost was assumed to be 1.2¢ per tonne km.
- Capital costs were converted to annual costs using a capital recovery rate of 10%, a 20-year life for all port and mine equipment, a 15-year life for steel covers and a 5-year life for fibreglass covers.
- All maintenance costs were assumed to be 4% of capital cost except the steel cover removal system and the covers which were assumed to be 1% and 2% of capital cost respectively.
- Labour costs were based on 1 man hour per train visit at the mine for chemical binders and 6 man hours at the mine and port to remove and replace fibreglass covers.
- Fibreglass covers weigh 680 kg and the automatic removal replacement system adds 4 hours to the loading-unloading cycle time and requires 2 operators, 1 at the port and 1 at the mine.
- Steel covers weigh 1 590 kg and increase the cost of rail car maintenance .6¢ per km travelled as they cannot be turned around.
- Chemical binders were assumed to reduce the carrying capacity of the rail cars by 225 kg.
- Transportation costs were estimated by using the dust control method of chemical binders as a base case and calculating the incremental costs associated with rail car covers.

The "standard case" estimated the amortized cost of permanent cover systems to be five times as great as chemical binder systems, however, the study incorporated certain assumptions with respect to cover system operations which significantly increased the cost estimates for covers.

The key assumption in the case of fibreglass covers was that the lift-off design would require an additional two hours to remove and replace covers at either end of a

journey. The authors of the study felt that adding four hours to the unit train round trip cycle would result in a requirement for additional rolling stock to maintain the same annual tonnage throughputs. The capital cost of the additional cars was included in the cost estimate for the fibreglass covers and significantly increased the amortized cost estimate for that type of dust control system. This assumption was not employed when making the revised cost estimates, Section C.2, since a cover system which could not operate within a four hour loading/unloading time constraint would be operationally unacceptable.

The cost estimate for the steel hinged-covers included an assumption related to preferential wheel-wear. Because covers are hinged to one side of a car and dumpers only rotate in one direction, it was assumed that cars could not be rotated, as per normal railway maintenance schedules, to equalize wheel-wear. An "extra rail car maintenance" factor was introduced which significantly increased the steel hinged cover cost estimate. However, since it is possible that a cover system could be designed (or an operational procedure developed) that would reduce or eliminate this economic penalty, the revised cost calculations (Section C.2) include two cost estimates, one with a wheel-wear penalty (the high case) and one without (the low estimate).

C.1.2 Cover Feasibility Study - Cost Comparison

In a study carried out for Environment Canada in 1982, (Ref. 9) cost comparisons were presented for steel hinged-lids and fibreglass lift-off cover systems in addition to chemical sealant sprays. The assumptions for these estimates were as follows:

- Movement of 10×10^6 tonnes of coal annually 1 100 km form 1 mine in southeast British Columbia to 1 port.
- Movement was made in 100 car unit trains, each having a capacity of 91 tonnes.
- Capital costs were converted to annual costs using a capital recovery rate of 15%, a 15 year life for steel covers, a 10 year life for fibreglass covers, a 20 year life for steel/fibreglass cover handling systems at mines and port, and a 20 year life for chemical spray systems.
- Annual maintenance costs were assumed to be 2% of the capital cost for chemical sealant sprays; 2% for steel covers and 1% for steel cover handling systems; 4% for fibreglass covers and 4% for fibreglass cover handling systems; and 2% for chemical spray systems.
- Labour costs were based on 4 man hours per train for the chemical sealant and fibreglass cover system. No operating labour charges were assumed for the steel cover system.
- Car under-utilization was based on reduced car capacity due to additional car weights: 0.4 tonnes/car for chemical sealants, 2.27 tonnes/car for steel covers and 1.1 tonnes/car for fibreglass covers. The reduced capacity was charged at a rate equivalent to $70 per tonne of coal.
- Transportation cost was assumed to be 1.5¢ per tonne-km.

- Cost of additional rail car maintenance due to preferential front wheel wear in cover car systems was assumed to be 2% of capital cost.
- Cost of chemical sealants was assumed to be 12¢ per tonne of coal.
- Product loss due to coal dust emissions for chemical sealant controls was assumed to be 0.15% (i.e.: 85% control applied to an uncontrolled emission factor of 1 tonne coal per car per trip).

The estimates in this study show only a small difference in the amortized cost of a fibreglass lift-off cover system compared to the long term costs of sprayed chemical sealants, however, a bias against chemical binders and in favour of cover systems was introduced when it was assumed that there was a frozen coal carry-back penalty for sprayed cars and none for covered cars. The industry's claim, that covers do not eliminate coal carry-back, has been confirmed by the operator of the automated cover system in the U.S.A., therefore the frozen coal carry-back penalty has been removed for both cover and spray system cost estimates (Section C.2).

The industry was also concerned about the product loss factor, (i.e. coal dust loss) included for chemical binders but not for covers, since this factor significantly biased the cost estimates against chemical sprays. Therefore, since losses are unsubstantiated and not a true system cost, the revised estimates include a low estimate, and a high estimate with no loss factor plus an estimate which includes the influence of a product loss factor (85% dust control of a 1% loss).

C.2 Revised Cost Estimates

Many of the parameters which influence the cost of dust control systems and which are used in cost estimating have not been, or cannot be, accurately determined. As noted previously, these uncertainties have lead to controversies with respect to the validity of cost estimates. Therefore, the revised estimates, presented below, incorporate "best" and "worst" assumptions with respect to unsubstantiated variables in order to illustrate the sensitivity of cost estimating. Three types of dust control systems have been considered: sprayed chemical sealants, a fibreglass lift-off cover system, and a steel hinged-cover system.

In order to compare the influence of individual parameters, a number of factors were fixed at one value for all systems. Table C1 lists the fixed cost factors which were used to estimate the base-case costs for the three control systems. All of the base-case estimates were developed with the values set as indicated.

TABLE C1 FIXED COST FACTORS

PARAMETER	VALUE
Labour	$20/hour
Transport Cost	$19/tonne
Coal Value	$60/tonne
Spray Chemical Cost	$1/litre
Car Capital Cost	$60 000
Coal Shipped	5 million tonnes per year
No. Coal Mines	2
No. Coal Ports	1
Haul Distance - one way	1 100 km
Travel Time - one way	41 hours
Average Cars per Train	100
Load per Car	91 tonne
Spare Train Sets Required	1%
Interest Rate	15%
Mine Facilities Life	20 years
Port Facilities Life	20 years

C.2.1 **Chemical Spray Systems.** In addition to the fixed factors listed in Table C1, the sensitivity cost estimates (Table C3) for this control system were generated assuming the following:

TABLE C2 SPRAY SYSTEM COST FACTORS

Case	Low	Base	High
- Labour at mine site:	1 hour	2 hours	4 hours
- Maintenance at mine site:	4	4% of capital cost	4
- Weight of fluid per car:	0.225	0.225 tonnes	0.450
- Litres of spray per car:	10	10	20
- Uncontrolled dust emissions:	1	1 tonne per car	1
- Percent dust control:	100%	100%	85%
- Weight of frozen coal:	0	0 tonnes per car	0

TABLE C2 SPRAY SYSTEM COST FACTORS (CONT'D)

Case	Low	Base	High
- Loading time:	4	4 hours	4
- Unloading time:	4	4 hours	4
- Round trips per year:	550	550	550
- Operating days per year:	330	330	330
- Cost of mine spray apparatus:	100,000	$200,000	$400,000
- Cost of back-up spray:	$0	$0	$0
- Cost of leveller:	$0	$0	$0

The spray system envisaged was similar to those already installed at the coal mine load-outs in western Canada. In addition to the low, base and high sensitivity cases, other parameters were tested for their influence on the base-case cost. The following (when they were the only parameter varied), were each shown to increase or decrease the amortized costs by a minimal amount:

- To account for chemical sealant spillage at the mine site add a cost factor of 1% per year.
- To allow for errors in maintenance estimates increase or decrease the maintenance required at the mine site by 1%.
- To operate a more complex load leveller/spray system increase the labour required per train at the mine site from 2 to 4 hours.
- To allow time for improved load-levelling increase the loading time from 4 to 5 hours but do not add extra car charges.
- Increase the working days per year from 330 to 365. (The net effect of this increase was nullified. The accepted practice when cost estimating has been to round-off train set and car requirements to the next higher integer, this round-off produced a buffer which absorbed the effect of an increase in the number of working days).
- To improve spray performance add a $100 000 back-up spray. (Changing no other parameters.)
- To improve spray performance add a $100 000 leveller. (Changing no other parameters.)
- To improve dust control add ONE $100 000 en route water spray device.
- To reduce empty car dusting add One $100 000 port located car wash.

TABLE C3 SPRAY SYSTEM COST ESTIMATES

Equipment and Material costs		Sensitivity Cases Low	Base	High
Capital Costs:	Mines	200,000	400,000	800,000
	Port	-	-	-
	Covers	-	-	-
Annual Costs:				
Capital Recovery:	Mines	31,960	63,920	127,840
	Ports	-	-	-
	Covers	-	-	-
Labour:	Mines	11,000	22,000	44,000
	Port	-	-	-
Maintenance:	Mines	8,000	16,000	32,000
	Port	-	-	-
	Covers	-	-	-
Materials	Spray	500,000	500,000	1,000,000
SUB-TOTAL		550,960	601,920	1,203,840
INDIRECT TRANSPORTATION COSTS				
- Displaced Cargo & Additional Time Costs		235,125	235,125	470,250
- Product Loss		-	-	(495,000)*
- Extra Rail Car Maintenance		-	-	-
TOTAL ANNUAL COST $		786,085	837,045	1,674,090 (2,169,090)*
Costs Per Tonne $		$0.16/tonne	$0.17/tonne	$0.34/tonne ($0.44/tonne)*

* The bracketed cost estimates include a product loss factor. Product loss en route due to fugitive dusting is not a true system cost, it has been included to indicate its importance with respect to other factors.

Other parameters appear to have a greater individual influence on sprayed chemical system cost. The quantity of commercial chemical sealant added per car has the greatest impact on the cost estimates.

C.2.2 **Fibreglass Lift-Off Cover System.** The base-case estimates for this example were made assuming an automatic, fibreglass, lift-off, carry-round, and replace cover design as presented in Reference 9.

In addition to the fixed factors, the following were assumed when calculating the sensitivity estimates (Table C5):

TABLE C4 FIBREGLASS COVERS COST FACTORS

Case	Low	Base	High
- Labour at the mine site:	4 hours	4 hours	6 hours
- Labour at the port:	4 hours	4 hours	6 hours
- Maintenance at the mine site:	4	4%	4
- Maintenance at the port:	4	4%	4
- Cover maintenance:	4	4%	4
- Cover weight:	0.7 tonnes	1.1 tonnes	1.1 tonnes
- Weight of frozen coal carry-back:	0	0 tonnes/car	0
- Loading time:	4	4 hours	4
- Unloading time:	4	4 hours	4
- Cost per cover:	$4 800	$4 800	$9 000
- Cost per cover installation:	$1 300	$1 300	$1 300
- Cost mine cover handling system:	$1.2 x 10^6	$1 200 000	$2.4 x 10^6
- Cost port cover handling system:	$1.2 x 10^6	$1 200 000	$2.4 x 10^6
- Spare cover requirement:	15	15%	15
- Cover life:	5 years	5 years	5 years

TABLE C5 FIBREGLASS LIFT-OFF COVER COST ESTIMATES

Equipment and Material costs		Sensitivity Cases Low	Base	High
Capital Costs:	Mines	2,400,000	2,400,000	4,800,000
	Port	1,200,000	1,200,000	2,400,000
	Covers	5,456,000	5,456,000	9,320,000
Annual Costs:				
Capital Recovery:	Mines	383,520	383,520	767,040
	Ports	191,760	191,760	383,520
	Covers	1,087,381	1,627,525	2,780,156
Labour:	Mines	44,000	44,000	66,000
	Port	44,000	44,000	66,000
Maintenance:	Mines	96,000	96,000	192,000
	Port	48,000	48,000	96,000
	Covers	218,240	218,240	372,800
Materials	Spray	-	-	-
SUB-TOTAL		2,112,901	2,653,045	4,723,516
INDIRECT TRANSPORTATION COSTS				
- Displaced Cargo & Additional Time Costs		731,500	1,149,500	1,149,500
- Product Loss		-	-	-
- Extra Rail Car Maintenance		-	-	-
TOTAL ANNUAL COSTS $		2,844,401	3,802,545	5,873,016
Costs Per Tonne $		$0.57/tonne	$0.76/tonne	$1.18/tonne

Amortization of the capital costs of cover systems over their useful operating lives and the displaced cargo penalties due to cover weight represent the major cost items for this system. Amortization is sensitive to the cover costs and the assumed operating life of each component.

C.2.3 Sectional Steel, Hinged-Cover System. In addition to the fixed factors, the following assumptions were made for the sensitivity estimates in Table C7:

TABLE C6 STEEL COVERS COST FACTORS

Case	Low	Base	High
- Labour at the mine site and port:	0	0 hours	0
- Maintenance at the mine site:	1	1%	1
- Cover maintenance:	2	2%	2
- Cover weight:	2.27 tonnes	2.27 tonnes	3.4 tonnes
- Weight of frozen coal carry-back:	0	0 tonnes/car	0
- Loading time:	4	4 hours	4
- Unloading time:	4	4 hours	4
- Cost per cover:	$9 000	$9 000	$9 000
- Cost per cover installation:	$1 900	$1 900	$1 900
- Cost of mine cover handling system:	$1 000 000	$1 000 000	$1 000 000
- Cost of mine retrofit (per mine):	$500 000	$500 000	$500 000
- Cover life:	15	15 years	15
- Extra maintenance due to wheelwear:	0%	2%	2%

TABLE C7 STEEL HINGED-COVER COST ESTIMATES

Equipment and Material costs		Sensitivity Cases Low	Base	High
Capital Costs:	Mines	1,200,000	1,200,000	1,200,000
	Port	-	-	-
	Covers	9,440,000	9,440,000	9,440,000
Annual Costs:				
Capital Recovery:	Mines	191,760	191,760	191,760
	Ports	-	-	-
	Covers	1,614,240	1,614,240	1,614,240
Labour:	Mines	-	-	-
	Ports	-	-	-
Maintenance:	Mines	12,000	12,000	12,000
	Port	-	-	-
	Covers	188,800	188,800	188,800
Materials	Spray	-	-	-
SUB-TOTAL		2,006,800	2,006,800	2,006,800
INDIRECT TRANSPORTATION COSTS				
- Displaced Cargo & Additional Time Costs		2,372,150	2,372,150	3,553,000
- Product Loss		-	-	-
- Extra Rail Car Maintenance		-	960,000	960,000
TOTAL ANNUAL COST $		4,378,950	5,338,950	6,519,800
Costs Per Tonne $		$0.88/tonne	$1.07/tonne	$1.31/tonne

The style of cover envisioned when making the base-case estimate was a long lasting, sectional, steel, hinged-cover system similar to the one in operation in the U.S.A. This system would require only the scroll type of lid-opening mechanism at the mine site and no modifications to the port unloading system (Ref. 9).

Cover costs, cover weight and extra wheel-maintenance appear to have the greatest impact on overall system cost. If the amount of extra wheel-maintenance could be reduced or eliminated than the cost penalty imposed by this parameter would be less and the system judged economically more attractive. Selecting a cover of the lightest practicable material will also reduce the cover weight cost penalty and reduce overall system cost.